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01 Evolution

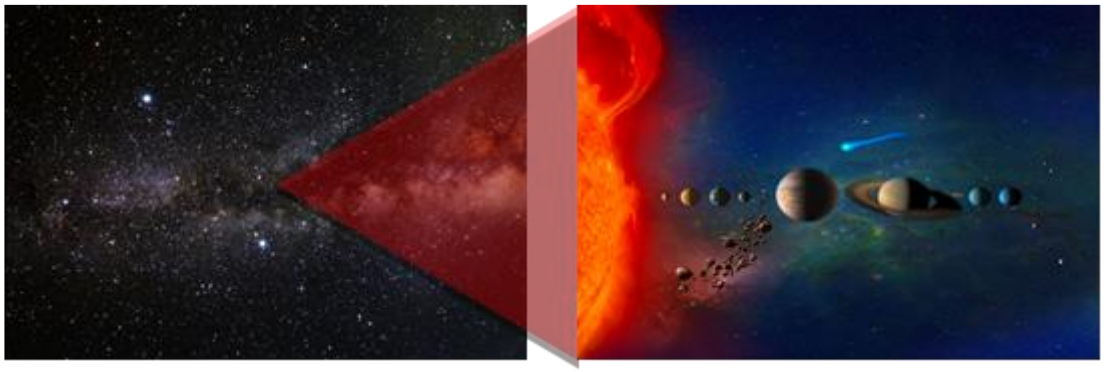
1. Introduction :

What is Evolution?

- The word evolution means to unfold or unroll or to reveal hidden potentialities. Evolution simply means an orderly change from one condition to another.
- It can be best explained by Darwin's concept of **'Descent with modification'**.

(A) Evolutionary Biology :

- It is the study of history of life forms i.e. the changes in flora and fauna that have occurred over millions of years on earth.
- To understand the changes in flora and fauna that have occurred over millions of years on earth, we must have an understanding of the context of origin of life, i.e., evolution of earth, of stars and indeed of the universe itself.
- What follows is the longest of all the construed and conjectured stories. This is the story of origin of life and evolution of life forms or biodiversity on planet earth in the context of evolution of earth and against the background of evolution of universe itself.



What is Universe?

- The universe is a huge cluster of galaxies. Galaxies contain stars and clouds of gas and dust. Considering the size of universe, earth is indeed a speck i.e. The universe is vast. So vast that the stellar distances are measured in light years.
- When we look at stars on a clear night sky we are, in a way, looking back in time. What we see today is an object whose emitted light started its journey millions of years back and from trillions of kilometres away and reaching our eyes now. However, when we see objects in our immediate surroundings, we see them instantly and hence in the present time. Therefore, when we see stars, we apparently are peeping into the past.
- The Big Bang theory attempts to explain to us the origin of universe.

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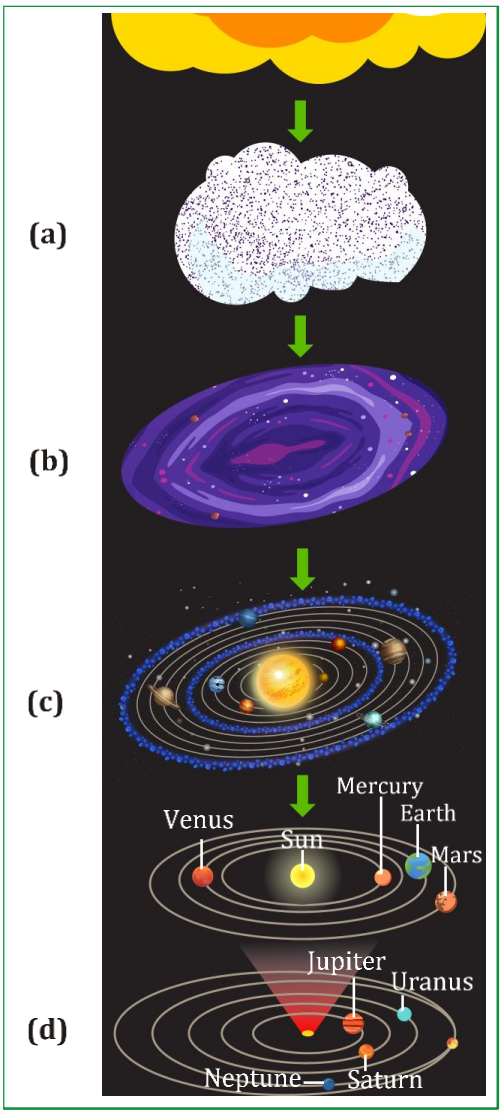
(B) Big Bang Theory- Proposed by Abbe Lemaitre :

- According to it, the universe originated about 20 billion years ago due to a thermonuclear explosion of a dense entity. This single huge explosion, which is unimaginable in physical terms, is called as **big bang**.
- The universe expanded and hence, the temperature came down. Hydrogen and Helium were formed sometime later.
- The gaseous clouds which were formed by the big bang condensed under gravitation and converted into many flat discs like structures called **nebula**, made up of atoms and small particles. **Solar nebula** was one of them, which formed our solar system.
- The very hot central part of solar nebula became even hotter due to pressure and converted into the sun.
- Later, due to condensation of atoms and dust particles moving around the sun, planets were formed.
- In the solar system of the **Milky Way galaxy**, earth was supposed to have been formed about **4.5 billion years** back.
- **There was no atmosphere on early earth. It was formed later.**



(C) Primitive Earth :

- There was no atmosphere on early earth but later, water vapour, methane, carbon dioxide and ammonia released from molten mass covered the surface.
- All the oxygen present at that time, combined with ammonia and methane to form water, CO_2 and others. As it cooled, the water vapor fell as rain, to fill all the depressions and form oceans.
- The conditions on earth were – high temperature, volcanic storms, lightening, unstable radioactive elements, UV rays, reducing atmosphere containing CH_4, NH_3, etc.
- **Life appeared 500 million years after the formation of earth, i.e., almost four billion years back.**
- The UV rays from the sun broke up water into Hydrogen and Oxygen and the lighter H_2 escaped.
- The ozone layer was formed.

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2. Theories for Origin of Life :

(A) Theory of Special Creation :

- The greatest supporter of this theory was Father Suarez. This is a mythology-based theory.
- This theory has three connotations-
  - All living organisms (Species or types) that we see today were created as such.
  - The diversity was always the same since creation and will be the same in future.
  - The earth is about 4000 years old.
- All these ideas were strongly challenged during the nineteenth century based on observations of Charles Darwin, Wallace etc. They believed that life forms varied over the periods of time.
- From fossils records and their dating, we can conclude that earth is very old, not thousands of years as was thought earlier but billions of years old.

(B) Cosmic Panspermia Theory :

- Some scientists believe that life came from outer space. Early Greek thinkers thought units of life called **spores** were transferred to different planets including earth.
- 'Panspermia' is still a favourite idea for some astronomers.

(C) Theory of Spontaneous Generation (Abiogenesis/Autogenesis) :

- For a long time, it was also believed that the life came out of decaying and rotting matter like straw, mud, etc. spontaneously.
- This hypothesis was supported by ancient Greek philosophers. They believed that the mud of river Nile could give rise to fishes, frogs, crocodiles etc when warmed by light rays.
- Louis Pasteur by careful experimentation demonstrated that life comes only from pre-existing life and not from dead matter.

(D) Theory of Biogenesis :

- Proposed by Harvey & Huxley They stated **"Omnis vivum ex ovo or vivo"**, which means "New life can originate from pre-existing life."
- Experiments of **Francesco Redi, Lazzaro Spallanzani, and Louis Pasteur** etc supported the theory of biogenesis and disproved the abiogenesis. Experiment of Louis Pasteur is most renowned among all of these.
- However, this theory did not answer how the first life-form came on earth.

Louis pasteur's swan neck flask experiment :

- Louis Pasteur prepared sterilized syrup of sugar and killed yeast by boiling them in flasks.
- He took two flasks, one of broken neck and another of curved neck (swan neck flask / "S" shaped neck flask).
- He showed that in pre-sterilized swan neck flasks, life did not come from killed yeast because germ laden dust particles in the air were trapped by the curved neck which serves as filter.
- However, in another flask open to air (broken neck), new living organisms arose.

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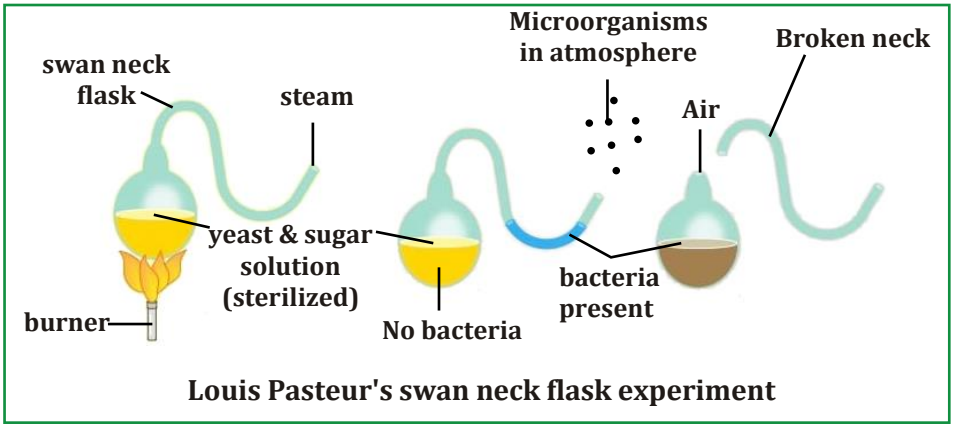

Louis Pasteur's swan neck flask experiment

(E) Oparin - Haldane Theory (Modern Theory) :

- Oparin of Russia and Haldane of England proposed that the first form of life could have come from pre-existing non-living organic molecules (e.g. RNA, protein, etc.) and that formation of life was preceded by chemical evolution, i.e., formation of diverse organic molecules from inorganic constituents.
- Oparin's theory was published in his book **'ORIGIN OF LIFE'**.
- **First life originated in sea water, so water is essential for origin of life.**
- Oparin-Haldane theory is studied in two parts – Chemogeny & Biogeny.

Chemical Evolution (Chemogeny) :

- Early earth had free atoms of all those elements which are essential for formation of protoplasm (C, H, O, N etc.) **Hydrogen was maximum among all of them.**
- Due to high temperature hydrogen reacted with oxygen to form water and no free oxygen was left, which made the atmosphere reducing. Hydrogen also reacted with nitrogen and formed ammonia.
- Hence, **water and ammonia were probably the first inorganic compounds formed on earth. Methane (CH_4) was the first organic compound.**
- As the earth cooled down, the water vapour fell as torrential rain, to fill all the depressions and form primitive oceans. Meanwhile, molecules continued to react with each other and formed various simple and complex organic compounds.
- Now, the water of oceans became a rich mixture of macromolecules/ complex organic compounds. Haldane called it **Hot dilute soup/ pre-biotic soup.**
- Hence, the possibilities of life were established in the water of primitive oceans because these macromolecules (Proteins, polysaccharides, fats/lipids, nucleic acids) form the main components of protoplasm.
- However, we have no clear idea about how the first self-replicating metabolic capsule of life arose, but we consider it to be a result of some mutations in the nucleic acids.

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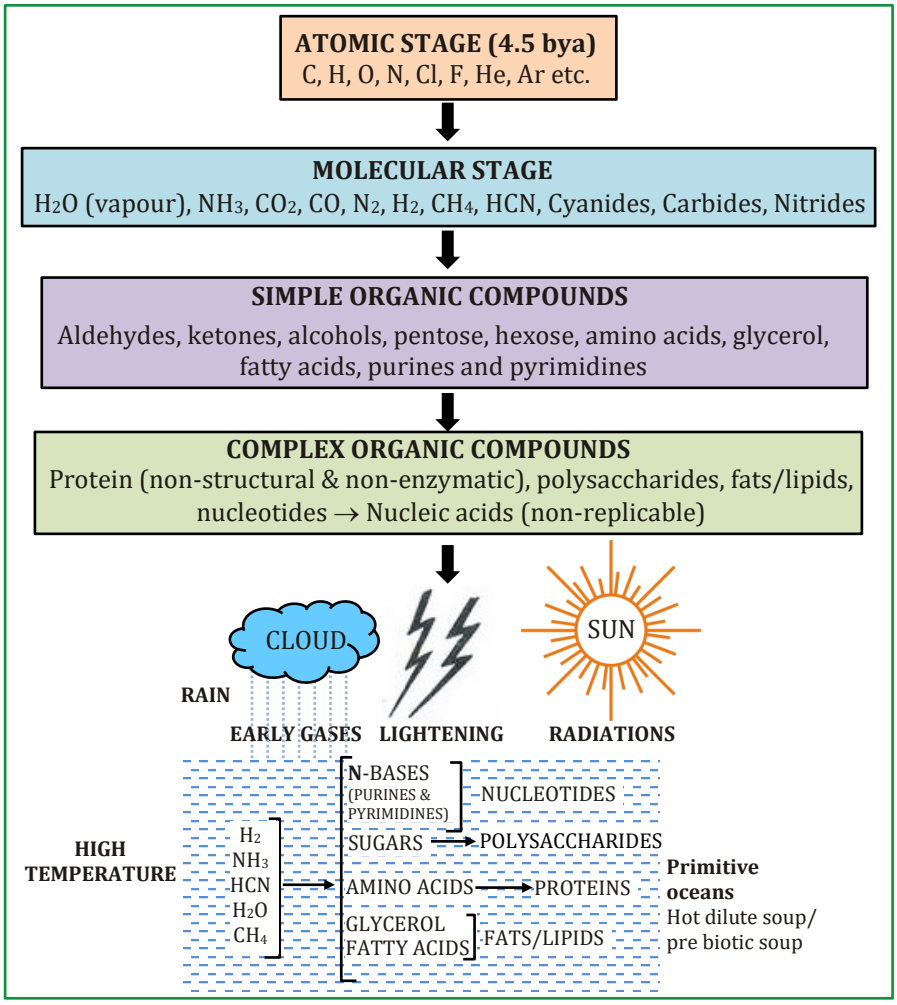
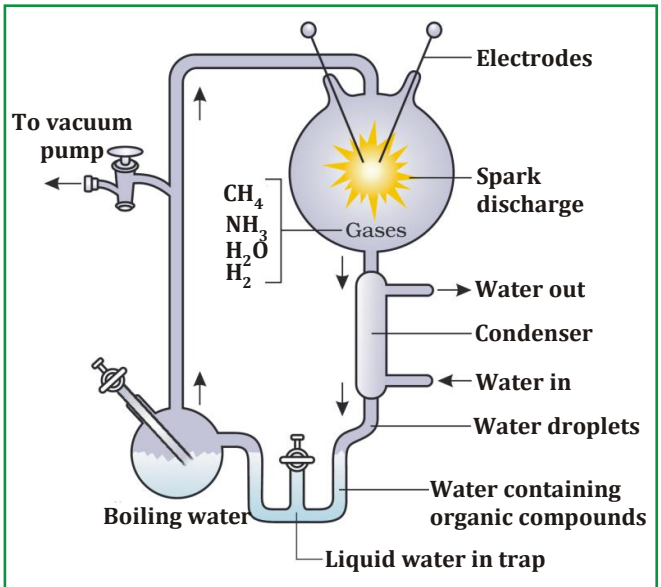


3. Evidence in Favour of Chemical Evolution :

(A) Harold Urey & Stanley Miller Experiment:

- In 1953, S.L. Miller, an American scientist created similar conditions at laboratory scale which were thought to be on primitive earth.
- He took CH_4, NH_3, H_2 and water vapour at 800°C in a large flask (spark flask).
- He created electric discharge by using two tungsten electrodes as source of energy to raise the temperature inside spark flask to 800° C.
- He observed the formation of simple amino acids like **glycine, alanine**, and **aspartic acid**.
- In similar experiments other scientists observed, formation of **sugars**, **nitrogen bases, pigments**, and **fats**.



Diagrammatic representation of Miller's experiment

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(B) Evidence From Meteorites:

- Analysis of meteorite contents also revealed similar compounds (nitrides, carbides, etc.) indicating that similar processes are occurring elsewhere in space.
- *With these limited evidences, the first part of the conjectured story, i.e., chemical evolution was more or less accepted.*

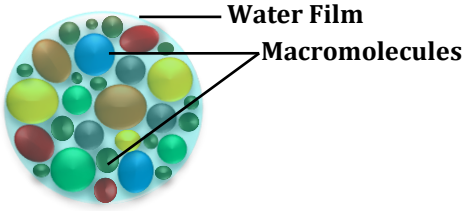
4. Theories for Origin of Life :

Oparin - Haldane Theory (Modern Theory):

(A) Biological Evolution (Biogeny) :

(i) Origin of Protobionts:

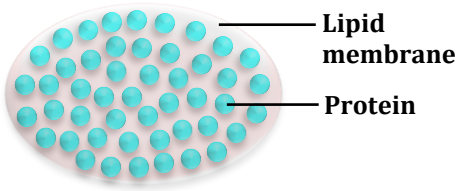
- Macromolecules which were synthesized abiotically in primitive oceans later came together and formed large colloidal drop like structures named as **protobionts**.



Properties of protobionts

(a) Partially isolated (b) Extrinsic growth (c) Could not reproduce
(d) Exhibit simple metabolism (e) Non-living

- However, Protobionts were also synthesized artificially by some scientists in laboratory.
- For example, **Oparin** prepared some protobionts without a lipid membrane and he called them **coacervates** (same properties as of natural protobionts).
- Similarly **Sydney Fox** synthesized some microscopic protenoid bodies with a lipid coat and called them **microspheres**.



(ii) Origin of protocells (Eobionts):

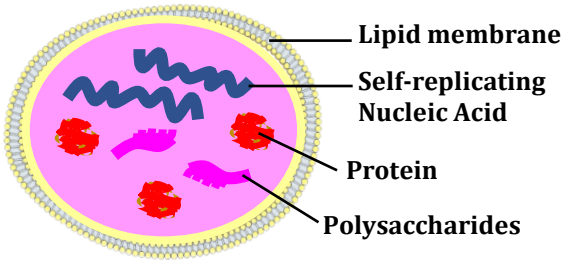
Non-Replicating Nucleic Acid $\xrightarrow{\text{Mutation}}$ Self-Replicating Nucleic Acid.

Self-Replicating Nucleic Acid + proteins $\longrightarrow$ Nucleoproteins

Nucleoproteins were the first sign of life.

1st form of Life : Eobiont – non-cellular

- These **first non-cellular forms** of life could have originated **3 billion years ago.**
- *Altman (1980) discovered that some RNA molecules have enzymatic activity, called as **ribozymes**. It means at the time of origin of life, RNA molecule could carry out all the basic processes of life (replication, protein formation enzymatic activity etc) without the help of either protein or DNA. Hence this concept is called as **RNA World**.*

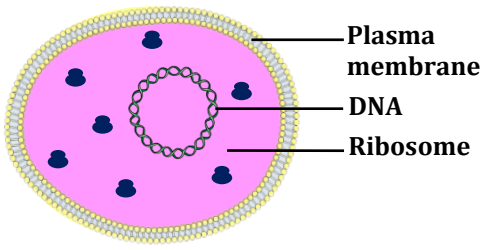


(iii) Origin of first cellular form (Prokaryotes):

- As a result of mutation protocells became more complex and efficient to use the materials available in the surrounding medium and evolved into prokaryotic cells.

RNA $\xrightarrow{\text{mutation}}$ DNA

Ribozymes & Proteins $\xrightarrow{\text{Organized}}$ Ribosomes



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- **This first cellular form of life did not possibly originate till about 2000 million years ago. (2 bya).**
- The first living beings were single celled bacteria like prokaryotes with naked DNA.
- **They were probably chemoheterotrophs and anaerobic.**
- *This version of abiogenesis, i.e., the first form of life arose slowly through evolutionary forces from non-living molecules is accepted by majority. However, once formed, how the first cellular forms of life could have evolved into the complex biodiversity of today is the fascinating story that will be discussed in organic evolution.*
- Some of the chemoheterotrophic bacteria evolved into chemoautotrophs. They were anaerobic and synthesized organic food from inorganic material; this mode of nutrition is called as chemosynthesis. e.g. Iron bacteria, Nitrifying bacteria etc.
- When bacteriochlorophyll was developed in some chemoautotrophic bacteria, they started to convert light energy into chemical energy, this mode of nutrition is called as photosynthesis. They used H_2S as source of hydrogen instead of H_2O hence they were non-oxygenic photosynthetic bacteria. e.g. Planktonic sulphur bacteria.
- Some molecular changes occurred in bacteriochlorophyll, and it transformed into true chlorophyll. Such organisms used H_2O as source of hydrogen and released oxygen in the environment, they were oxygenic photosynthetic bacteria. e.g. Cyanobacteria (Blue green algae).

(B) Evolution in Mode of Nutrition in Prokaryotes :

Chemoheterotrophs : Absorbed organic matter dissolved in oceans

↓

Chemoautotrophs : Synthesized organic food from inorganic material by the process of chemo-oxidation

Eg. Iron bacteria.

↓

Non-oxygenic Photoautotrophs : $CO_2 + H_2S \xrightarrow[\text{bacteriochlorophyll}]{\text{sunlight}}$ Glucose + Sulphur ↑

Eg. Sulphur bacteria

mutation ↓

Oxygenic Photoautotrophs : $CO_2 + H_2O \xrightarrow[\text{sunlight}]{\text{chlorophyll}}$ Glucose + O_2 ↑

Eg. Cyanobacteria (BGA)

(C) Oxygen Revolution :

- Liberation of free oxygen by cyanobacteria was a revolutionary change in the history of earth. It includes some major changes like-

1. Atmosphere of earth changed from reducing to oxidizing, hence possibilities of further chemical evolution finished, because chemical evolution always takes place in reducing environment.
2. Free O_2 oxidized CH_4 and NH_3 to form CO_2, N_2 and H_2O, etc.
3. Accumulation of free oxygen formed a layer of ozone outside the atmosphere of earth which started to absorb most of the UV rays of sunlight.
4. Some prokaryotes adapted themselves for aerobic mode of respiration which provides approximately 20 times more energy than anaerobic respiration.

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Origin of Eukaryotic Cell :

- Nucleus, mitochondria, and other cell organelles developed in the cell and the cell became metabolically more active. These free living unicellular eukaryotic organisms originated about **1.5 billion years ago** in the primitive ocean.

5. A Brief Account of Evolution :

- About 2000 million years ago (mya) the first cellular forms of life appeared on earth.
- By the time of 500 mya, invertebrates were formed and became active.
- Jawless fishes probably evolved around 350 mya.
- Sea weeds and few plants existed probably around 320 mya.
- **The first organisms that invaded land were plants**. They were widespread on land when animals invaded land.
- Fish with stout and strong fins could move on land and go back to water. This was about 350 mya. In 1938, a fish caught in South Africa happened to be a Coelacanth which was thought to be extinct.
- These Coelacanth or lobefins evolved into the first amphibians that lived on both land and water. There are no specimens of these left with us. However, these were ancestors of modern day frogs and salamanders.

- The amphibians evolved into reptiles. They lay thick shelled eggs which do not dry up in sun unlike those of amphibians. Again, we only see their modern day descendants, the turtles, tortoises and crocodiles.
- Synapsids were the mammal like early reptiles which gave rise to mammals.

- Sauropsids were the lizard like early reptiles which gave rise to different dinosaurs, modern reptiles and birds.
- In the next 200 million years or so, reptiles of different shapes and sizes dominated on earth.
- Giant ferns (pteridophytes) were present, but they all fell to form coal deposits slowly.
- Some of the land reptiles went back into water to evolve into fish like reptiles probably 200 mya **(e.g. *Ichthyosaurs*)**.
- The land reptiles were, of course, the dinosaurs. The biggest of them, was ***Tyrannosaurus rex*** about 20 feet in height and had huge fearsome dagger like teeth.
- About 65 mya, the dinosaurs suddenly disappeared from the earth. We do not know the true reason. This may have happened because (i) Climatic changes killed them or (ii) Meteorites' collisions killed them. Moreover, some say that most of them evolved into birds. The truth may live in between.
- Small sized reptiles of that era still exist today.
- The first mammals were like shrews. Their fossils are small sized.
- Mammals were viviparous and protected their unborn young inside the mother's body. Mammals were more intelligent in sensing and avoiding danger at least.
- When reptiles came down mammals took over this earth.

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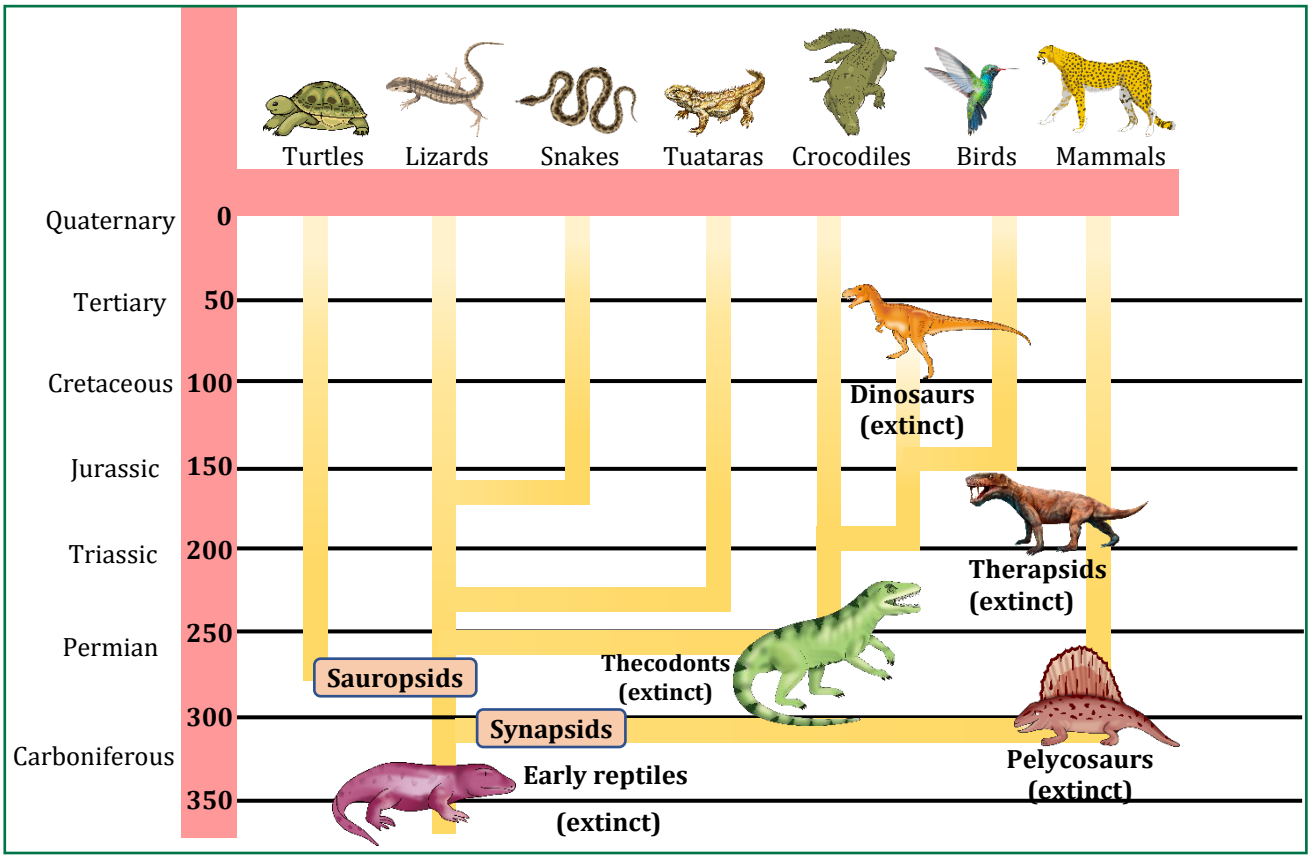

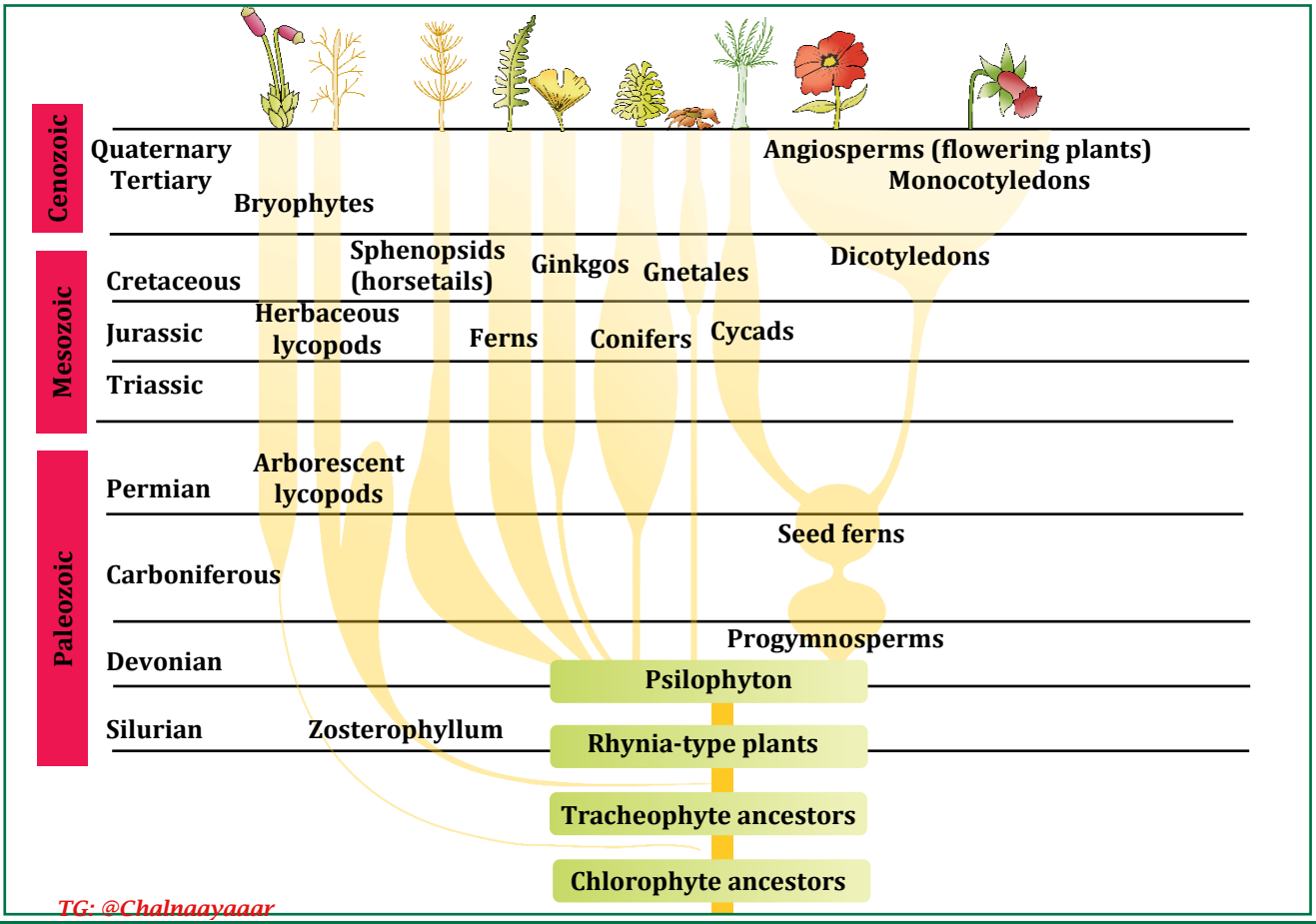

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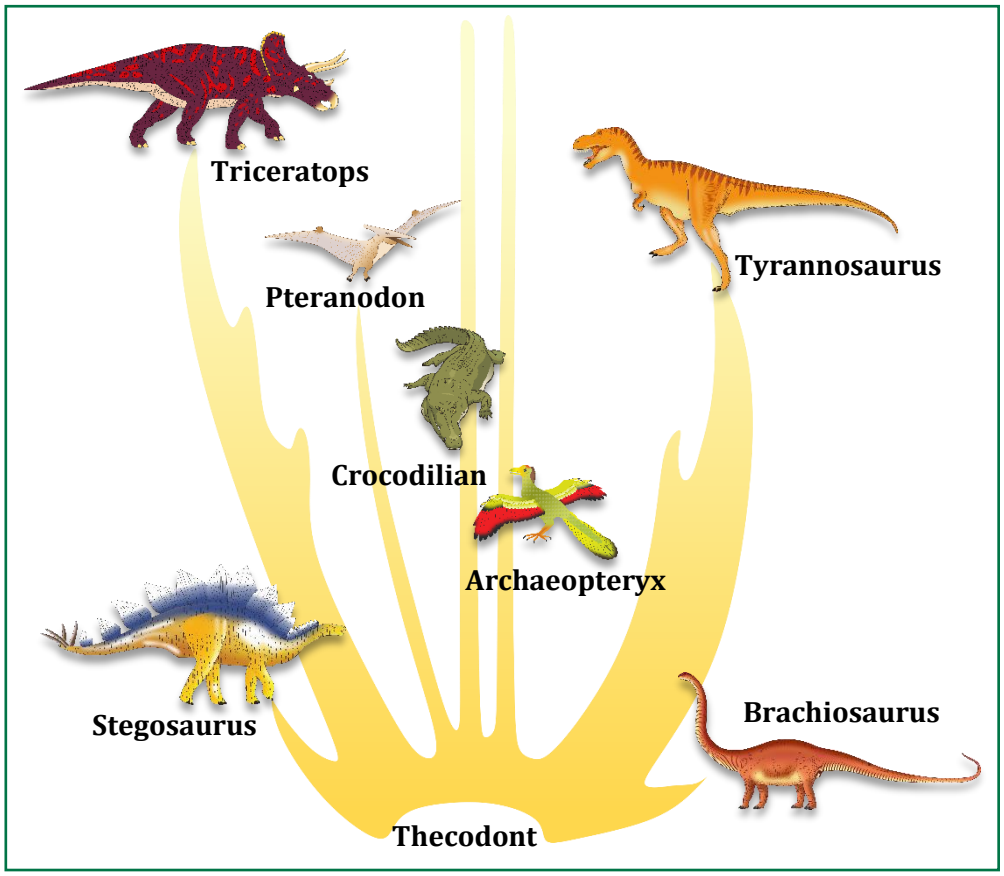

Golden Key Points

- Evolution of giant organic molecules from simpler inorganic constituents - **Chemical evolution**
- Evolution from macromolecule aggregates/coacervate to simple cell - **Biological evolution**
- Evolution from simple cell to recent - **Organic evolution**
- Oparin's theory is also known as primary abiogenesis and it is based on artificial synthesis, so also called as artificial synthetic theory.
- Louis Pasteur also proposed the **'Germ theory of diseases'** and he is famous for his **pasteurization technique**.
- From protocells or eobionts few core of nucleoproteins get separated free in oceans and became inactive but when they enter in another eobionts they became active so virus like structures were formed. This is an example of **retrogressive evolution**.
- **Universe** originated about **20 bya**.
- **Solar system** and **earth** were formed about **4.5 bya**.
- **Life** appeared about **4 bya**.
- Non-cellular form of life appeared – **3 bya**.
- First cellular form of life – **2 bya**.

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BEGINNER'S BOX-1

BIG BANG THEORY, THEORIES OF ORIGIN OF LIFE

1. How old is the universe?
(1) 20 million years (2) 20 billion years
(3) 04 billion years (4) 04 million years

2. How old is the earth?
(1) 4.5 billion years (2) 04 million years
(3) 4000 years (4) 400 years

3. Which of the following was not found in free form during origin of life ?
(1) Ammonia (2) Methane (3) Oxygen (4) Hydrogen

4. UV rays from the sun broke up___ into Hydrogen & Oxygen and the lighter__ escaped.
(1) Ammonia, H_2 (2) Water, O_2 (3) Water, H_2 (4) Ammonia, O_2

5. Who gave experimental proof that hydrogen, methane, water and ammonia gave rise to amino acids ?
(1) Stanley Miller (2) Charles Darwin (3) Lamarck (4) Oparin

6. Life originated in :
(1) Air (2) Earth (3) Water (4) None of them

7. Life originated :
(1) 8 billion years ago (2) 6 billion years ago
(3) 4 billion years ago (4) 1 billion years ago

8. Stanley Miller synthesized in his experiment :
(1) Virus (2) Protein (3) Amino acid (4) Cell

9. Nucleoproteins gave first sign of :
(1) Species (2) Evolution (3) Life (4) None

10. Life cannot originate from inorganic materials at present because :
(1) High degree of environmental pollution
(2) A very high amount of oxygen in the atmosphere
(3) Very high atmospheric temperature
(4) Absence of raw materials

11. The flat discs like structures formed due to condensation of gaseous clouds after big-bang were called as :
(1) Planets (2) Sun (3) Nebula (4) Galaxy

12. Swan neck flask experiment proved :
(1) biogenesis (2) abiogenesis
(3) special creation (4) both (1) and (2)

13. First organisms to evolve on the earth were:
(1) saprotrophs (2) autotrophs (3) heterotroph (4) plants

14. In the Stanley Miller experiment, how much was the temperature inside the spark flask?
(1) 800°C (2) 8000°C (3) 100°C (4) 80°C

15. Which of the following is not true for eobionts?
(1) Living (2) Partially isolated
(3) Cellular (4) Had RNA

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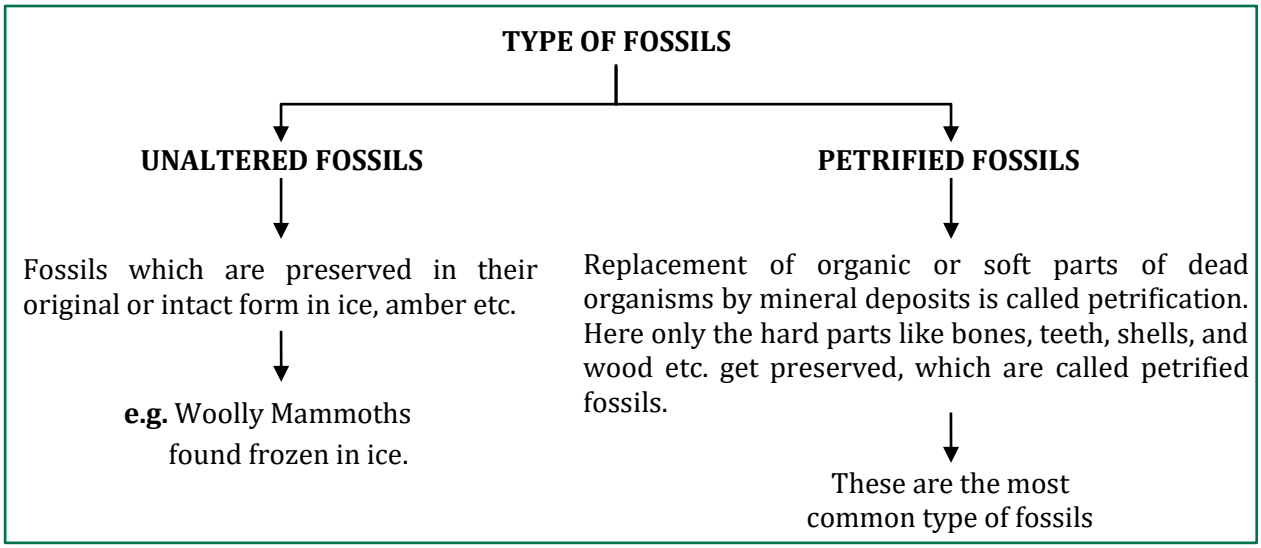
6. Evidences of Organic Evolution :

(A) Palaeontological Evidences :

- Study of fossils is called palaeontology.
- According to Charles Lyell, Fossils are impression or remains of hard parts of life-forms found in rocks.
- Rocks form sediments and a cross-section of earth's crust indicates the arrangement of sediments one over the other during the long history of earth. Such types of rocks are called as sedimentary rocks.
- Mostly fossils are found in sedimentary rocks.
- Different-aged rock sediments contain fossils of different life-forms who probably died during the formation of that sediment.
- A study of fossils in different sedimentary layers indicates the geological period in which they existed.
- Some of them represent extinct organisms (e.g., Dinosaurs).
- The study shows that life-forms varied over time and certain life forms are restricted to certain geological time spans.
- New forms of life have arisen at different times in the history of earth. i.e. evolution has taken place.
- Generally, fossils found in older rocks are of simpler types and found in newer rocks are of both simple and complex type.
- By fossils we can study the evolutionary pedigree of animals like horse, elephants and man etc.
- **The geological history of earth closely correlates with the biological history of earth.**


TYPE OF FOSSILS
UNALTERED FOSSILS
PETRIFIED FOSSILS
Fossils which are preserved in their original or intact form in ice, amber etc.
e.g. Woolly Mammoths found frozen in ice.
Replacement of organic or soft parts of dead organisms by mineral deposits is called petrification. Here only the hard parts like bones, teeth, shells, and wood etc. get preserved, which are called petrified fossils.
These are the most common type of fossils

How the ages of the fossils are calculated?

Answer: To find out the correct age of fossils, we determine the age of rocks from which fossils are found. Rocks contain some radioactive elements that decay and convert into their more stable forms. This radioactive decay takes place at a constant rate for each radioactive element irrespective of the environmental conditions.

It is already calculated that how long it will take for half the quantity of the element to change into its stable form, and this time is known as its half-life. After another half-life has passed, the element will have decayed to a quarter of its original amount and so on.

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For example: half-life of carbon-14 is 5730 ± 40 years; it means in 5730 ± 40 years, half of the C-14 converts into its stable form N-14.

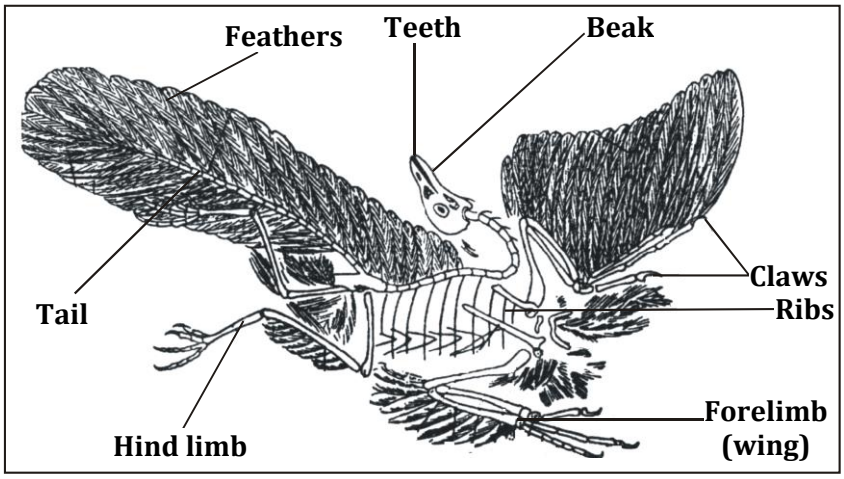
Thus we can calculate the age of rocks by relative proportions of radioactive element and non-radioactive element in a sample of rock. This method is called radioactive dating.

There are several methods used to determine the age of fossils-

(1) Uranium lead method
(2) Radio carbon method
(3) Potassium argon method
(4) Electron spin resonance (ESR) method - this is the modern and most accurate technique.

Archaeopteryx:

- It is a missing link between reptiles and birds.
- The connecting links which are not found in present times are called as Missing links.
- Its fossil was discovered by Andreas Wagner from Bavaria in Germany.
- It was found in the rocks of Jurassic period.



Reptilian characters:	Avian Characters:
Long lizard like tail with free caudal vertebrae	Feathers on body
Non-pneumatic bones	Jaws modified into beak
Weak sternum	Forelimbs modified into wings (reduced)
Teeth present in jaw	Hind limbs built in avian plan

(B) Connecting Links :

Some organisms possess characters of two separate groups called as connecting links, which proves that members of higher groups have evolved from the lower group. Examples:

- Virus - Between living and non living
- Euglena - Between plants and animals
- Proterospongia - between Protozoa and Porifera
- Neopilina - between Annelida and Mollusca
- Peripatus - between Annelida and Arthropoda
- Balanoglossus - between Non-Chordata and Chordata
- Chimera - between Cartilaginous and Bony fishes
- Protopterus (Lung fish) - between Pisces and Amphibia
- Seymauria - between Amphibia and Reptilia
- Archaeopteryx - between Reptilia and Aves
- Platypus and Echidna - between Reptilia and Mammalia

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BEGINNER'S BOX-2 PALAEONTOLOGICAL EVIDENCES

1. The first cellular form of life appeared on earth about:
(1) 4000 mya (2) 500 mya (3) 2000 mya (4) 3000 mya

2. The mammal like early reptiles which gave rise to mammals, are called as:
(1) Sauropsids (2) Thecodonts (3) Coelacanth (4) Synapsids

3. Dinosaurs disappeared from earth approximately:
(1) 320 mya (2) 350 mya (3) 65 mya (4) 200 mya

4. Fossils are dated by :
(1) Amount of calcium residue (2) Amount of radioactive carbon
(3) Association with other mammals (4) Structure of bones

5. The organisms which evolved into first amphibians were:
(1) Sauropsids (2) Coelacanth (3) Ichthyosaurs (4) Synapsids

6. About 200 million years ago some land reptiles went back into water to evolve into fish like reptiles, these were:
(1) Ichthyosaurs (2) Coelacanth (3) Blue whale (4) Sauropsids

7. Jawless fishes evolved around:
(1) 500 mya (2) 350 mya (3) 320 mya (4) 200 mya

8. Which among the given options was a flying reptile?
(1) *Tyrannosaurus* (2) *Pteranodon* (3) *Archaeopteryx* (4) *Stegosaurus*

9. Dinosaurs originated :
(1) After evolution of mammals (2) With mammals
(3) Much before mammals (4) Before mammals and they formed them

10. Which of the following is an unaltered fossil?
(1) Archaeopteryx (2) Wooly mammoth
(3) Humans (4) Both (1) and (2)

11. Geological history of earth closely corelates with the -
(1) Biological history of earth (2) Geological history of mars
(3) Political history of world (4) Modern history of the world

12. Neopilina is a connecting link between -
(1) Annelida and Arthropoda (2) Mollusca and Echinodermata
(3) Annelida and Mollusca (4) Coelenterata and Porifera

13. Which of the following got converted into coal deposits that we see today?
(1) Monocots (2) Dicots (3) Gnetales (4) Giant ferns

14. Mostly fossils are found in which rocks?
(1) Metamorphic rocks (2) Sedimentary rocks
(3) Igneous rocks (4) Both 1 and 3

15. How many of the following are connecting links between reptile and mammals?
Platypus; Archaeopteryx; Echidna; Seymauria
(1) Two (2) Three (3) Four (4) One

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(C) Comparative Morphology and Anatomy :

Similarities and differences are found among organisms of today and those that existed years ago. Such similarities can be interpreted to understand whether common ancestors were shared or not.

These similarities are of two types-

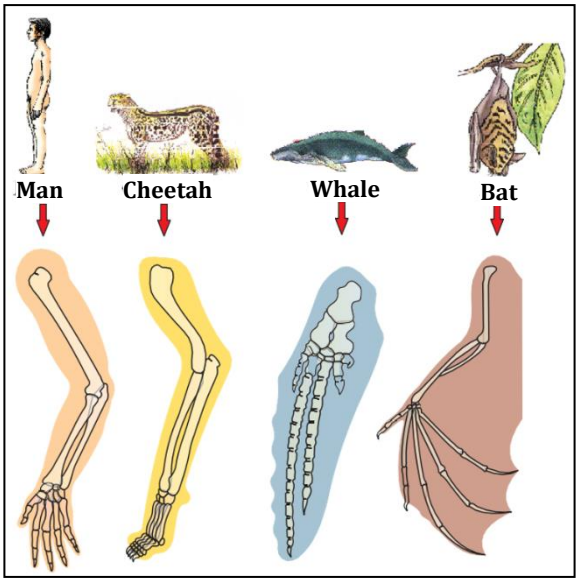
(1) Homology **(2) Analogy**

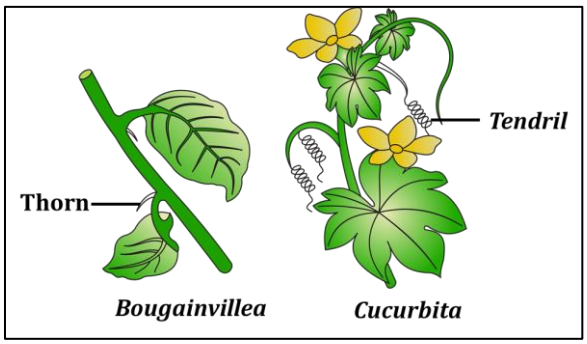
(1) Homology :

- The organs which have common origin, embryonic development and same fundamental structure but perform similar or different functions are called as Homologous organs and this phenomenon is called Homology.

Examples of homologous organs :-

(i) Forelimbs of mammals - Whales, bats, Cheetah and human (all mammals) share similarities in the pattern of bones of forelimbs though these forelimbs perform different functions. In these animals, forelimbs have similar anatomical structure - all of them have humerus, radius, ulna, carpals, metacarpals and phalanges in their forelimbs.





(ii) Thorn of Bougainvillea and tendril of Cucurbita both are modification of axillary bud.

(iii) hearts of vertebrate

(iv) brains of vertebrate

(v) Mouth parts of insects – In each of these insect's mouth parts comprise labrum, mandible maxilla etc.

Cockroach	Honey bee	Mosquito
(Biting & chewing)	(Chewing & lapping)	(Piercing & Sucking)

(vi) Testes in male and ovaries in female

(vii) Potato and Ginger - both are modified shoot

(viii) Radish and Carrot - both are modified roots

Molecular homology - Homology found at molecular level, can also be termed as evidence from biochemistry.

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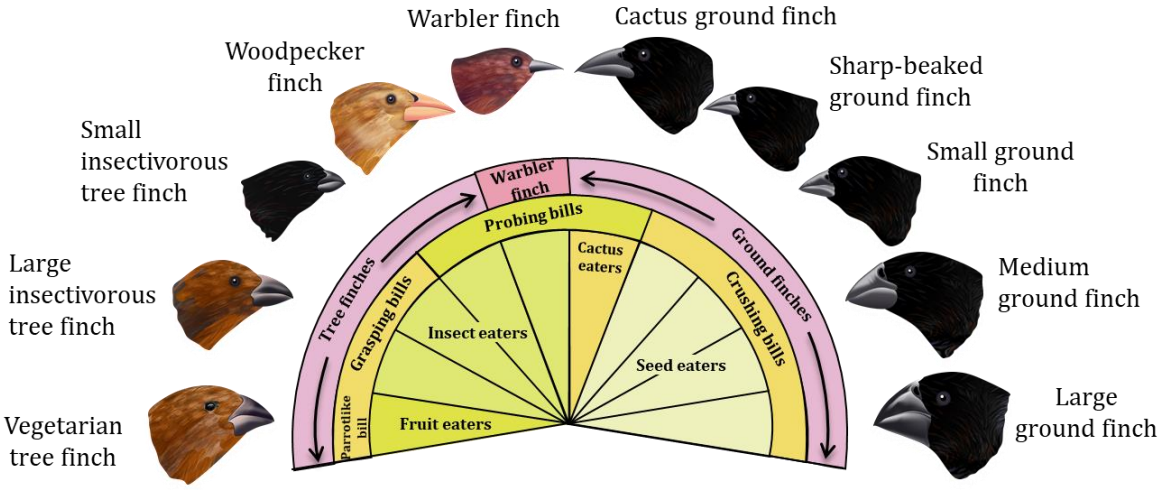
Similarities in proteins and genes performing a given function among diverse organisms give clues to common ancestry. Composition and structure of protoplasm, enzymes, hormones, DNA, blood in chordates is also almost same. It shows that organisms shared ancestors in recent or distant past. For example, the plasma proteins found in the blood of man and apes are similar, ABO Blood grouping is present in apes also.

WHAT IS ADAPTIVE RADIATION/ADAPTIVE DIVERGENCE?

The process of evolution of different species in a given geographical area starting from a point and literally radiating to other areas of geography (habitats) is called adaptive radiation. Homology based on Divergent evolution.

Examples:

(i) **Darwin's finches** - During the journey of Galapagos Islands, Darwin observed an amazing diversity of creatures. Of particular interest, small black birds later called Darwin's Finches amazed him.
Galapagos island is situated near south America which is a group of 22 smaller islands.
He realized that there were many varieties of finches at Galapagos island. All the varieties, he conjectured, evolved on the island itself. From the original seed-eating features, many other forms with altered beaks arose, enabling them to become insectivorous and vegetarian finches.



Variety of Darwin finches

(ii) **Australian Marsupials** - A number of marsupials, each different from the other evolved from an ancestral stock, but all within the Australian island continent.

(iii) **Placental Mammals** - A number of placental mammals have evolved from a common ancestral type in other parts of world also. Placental mammals in Australia also exhibit adaptive radiation.

Convergent evolution or Adaptive convergence -

When more than one adaptive radiation appeared to have occurred in an isolated geographical area (representing different habitats), one can call this convergent evolution.

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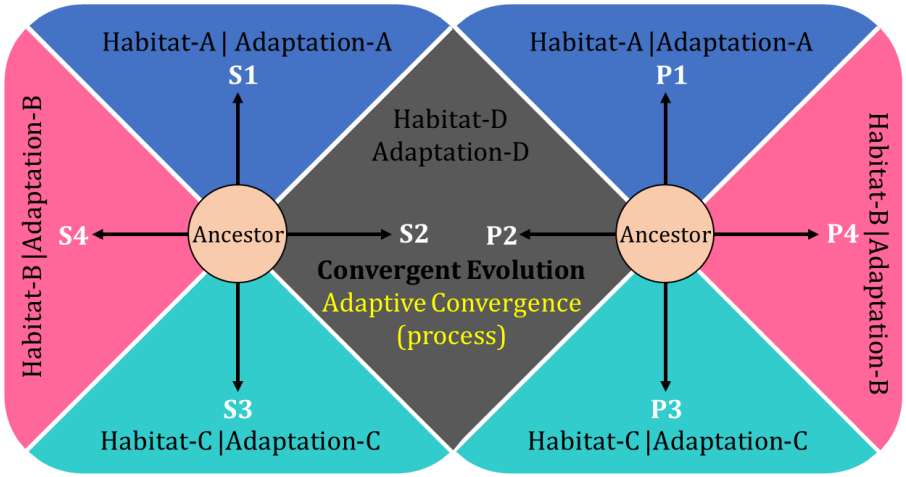
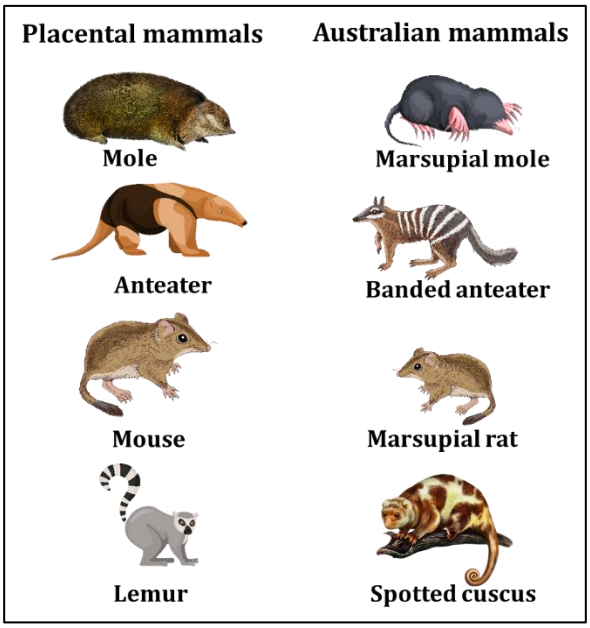
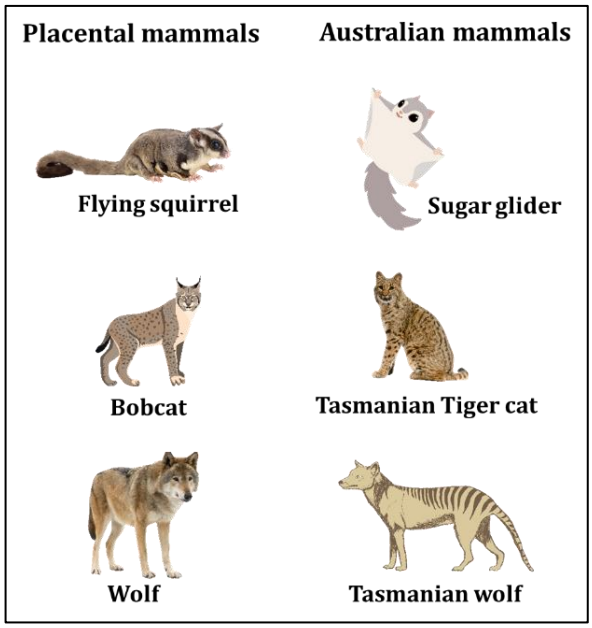


(2) Analogy :

- The organs which have different origin and fundamental structures but perform similar functions are called Analogous organs and this phenomenon is called as analogy.
- When different structures evolve for the same function due to the similar habitat or adaptations this is called convergent evolution. Analogy doesn't indicate common ancestry.
- **Placental mammals** in Australia also exhibit adaptive radiation in evolving into varieties of such placental mammals each of which appears to be 'similar' to a **corresponding marsupial**.
  e.g. **Wolf** (placental) and **Tasmanian wolf** (marsupial)





(i) **Wings of butterfly and birds** - They are not anatomically similar structures though they perform similar functions i.e. used for flying.
(ii) **Eye** of the octopus and mammals
(iii) **Flippers** of Penguins and Dolphins
(iv) Sweet potato (**root modification**) and potato (**stem modification**)
(v) **Sting** of bee and scorpion
(vi) **Chloragogen cells** of earthworm and **liver** of vertebrates.

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- When different structures evolve for the same function due to the similar habitat, this is called **convergent evolution**.
- Analogy doesn't indicate common ancestry and it is based on convergent evolution where different group of organisms have similar adaptive features due to similar habitat or towards the same function, hence analogous structures are a result of convergent evolution.

Flippers of Penguins and Dolphins

Eye of the octopus and of mammals

Sting of bee and scorpion

Wings of butterfly and birds

Sweet potato (root modification) and potato (stem modification)

Convergent evolution or Adaptive convergence -

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  e.g. **Wolf** (placental) and **Tasmanian wolf** (marsupial).
- **Parallel evolution-** When adaptive convergence is found in closely related species, it is called as parallel evolution.
- Parallel evolution occurs when two independent but similar species evolve in the same direction and thus independently acquire similar characteristics.

(D) Embryology :

- **Baer's law**: This was proposed by **Von Baer** (father of embryology). He stated that "in embryonic stages general characters appear firstly and specialized characters appear later".
- In 1866, **Ernst Haeckel** proposed **'Biogenetic law'** which explained "**Ontogeny recapitulates phylogeny**"
- Ernst Haeckel law was based on the observation of certain features during embryonic stage common to all vertebrates that are absent in adult for example the embryos of all vertebrates including humans develop a row of vestigial gill slits just behind the head but it is functional organ only in fish and not found in any other adult vertebrates.

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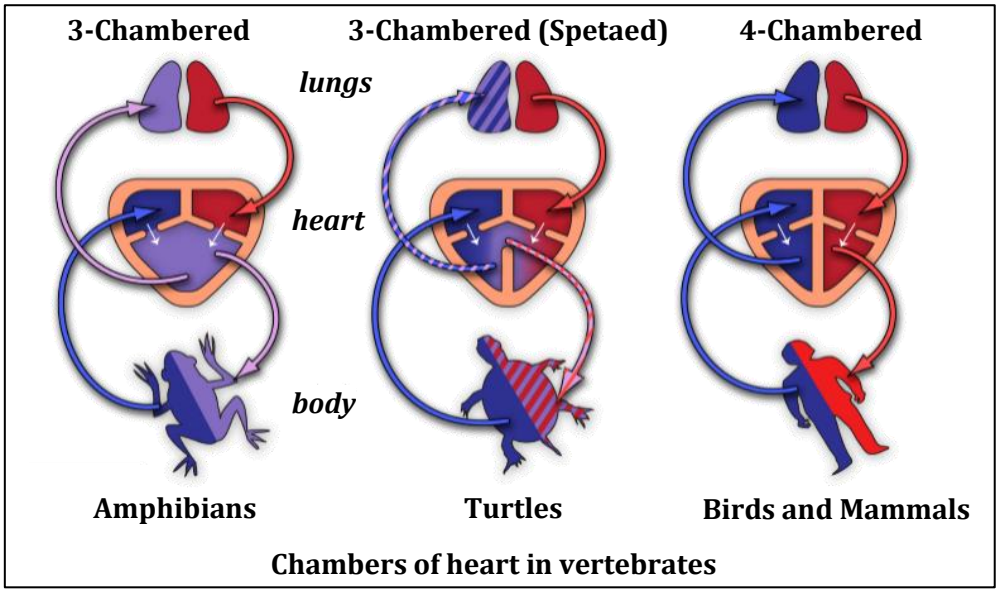
- It means an organism shows its ancestral adult stages during its embryonic development. In other words, embryos of advanced species pass through stages represented by adult organisms of more primitive species.
- It shows that all organisms have common ancestry.
- Interestingly, Von Baer (1828) had disproven the 'Biogenetic law' before Haeckel invented it. He observed that embryos never pass through the adult stages of other animals.

Examples:

(1) The **tadpole** (larva of amphibians) resembles with **fishes**. This indicates origin of amphibians from fishes.

Tadpole (Larva)

(2) During the development of heart in higher vertebrates like birds & mammals, it initially exhibits the 2– chambered state same as fishes. Later on, it develops into 3– chambered as in amphibians & reptiles and finally in the last embryonic stages it becomes 4– chambered as present in the adults. This proves that all vertebrates have evolved from common fish like ancestors and also that both birds & mammals have evolved from reptiles.



Chambers of heart in vertebrates

Evidences From Biogeographical Distribution :

- The study of geographical distribution of animals and plant species in different parts of earth is called as biogeography.
- On the basis of fauna and flora **Alfred Russel Wallace** divided the whole world into **six** biogeographical regions called **realms**.
- In South America, mammals resembling horse, hippopotamus, bear, rabbit, etc. were present. Due to continental drift, when South America joined North America, these animals were overridden by North American fauna.
- In prehistoric time Australia was a part of Asian continent. After the evolution of prototherians from reptiles Australia got separated from mainland of Asia. Later on eutherian mammals evolved in Asia which were carnivores in nature and they destroyed prototherians and marsupials from Asia but pouched mammals (marsupials) of Australia survived because of lack of competition from any other mammal.

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BEGINNER'S BOX-3

EVIDENCES FROM COMPARATIVE MORPHOLOGY AND ANATOMY, ADAPTIVE RADIATION

1. Archaeopteryx is a connecting link because :
(1) It possessed characters of reptiles and aves
(2) It had characters of reptiles and mammals
(3) It was a reptile not a bird
(4) It had characters of non chordates and chordates

2. Which of the following organ in man is not vestigial ?
(1) Vermiform appendix (2) Nictitating membrane
(3) Ear muscles (4) Epiglottis

3. According to recapitulation theory :
(1) Every animal begins as an egg (2) Damaged body parts are formed new
(3) Offsprings are like parents (4) Ontogeny repeats phylogeny

4. Homologous organs have :
(1) Similar origin and similar or dissimilar functions.
(2) Dissimilar origin and structure
(3) Dissimilar origin and function
(4) Dissimilar origin and similar functions

5. Galapagos islands are connected with which scientist ?
(1) Wallace (2) Lamarck (3) Malthus (4) Darwin

6. Prototheria have developed from :
(1) Birds (2) Eutheria (3) Amphibia (4) Reptilia

7. Analogous organs are :
(1) Similar in origin (2) Similar in structure
(3) Non functional (4) Similar in function

8. Forelimbs of humans and wings of birds are :
(1) Analogous organs (2) Homologous organs
(3) Parallel organs (4) Vestigial organs

9. Evolutionary history of an organism is known as :
(1) phylogeny (2) ancestry (3) palaeontology (4) ontogeny

10. Which of the following provides most evident proof of evolution ?
(1) Fossils (2) Morphology (3) Embryo (4) Vestigial organs

11. Which ones are not analogous organs?
(1) Wings of birds and wings of butterfly
(2) Eye of Octopus and eye of mammals
(3) Flippers of penguins and flippers of Dolphin
(4) Thorn of *Bougainvillea* and tendril of *Cucurbita*

12. Which of the following marsupial shows convergence with flying squirrel?
(1) Numbat (2) Lemur (3) Sugar glider (4) Wombat

13. Which of the following pair is of analogous organs?
(1) Human heart & heart cheetah (2) Sting of scorpion and honeybee
(3) Wings of bat and hand of man (4) Testes in male and ovaries in female

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14. Homology is based upon -
(1) Convergent evolution (2) Divergent evolution
(3) Retrogressive evolution (4) Both 1 and 2

15. Which of the following are example of adaptive radiation ?
(1) Darwin's finches (2) Placental mammals
(3) Australian marsupials (4) All of the above

7. Theories of Organic Evolution :

LAMARCKISM/ Theory of Inheritance of Acquired Characters :

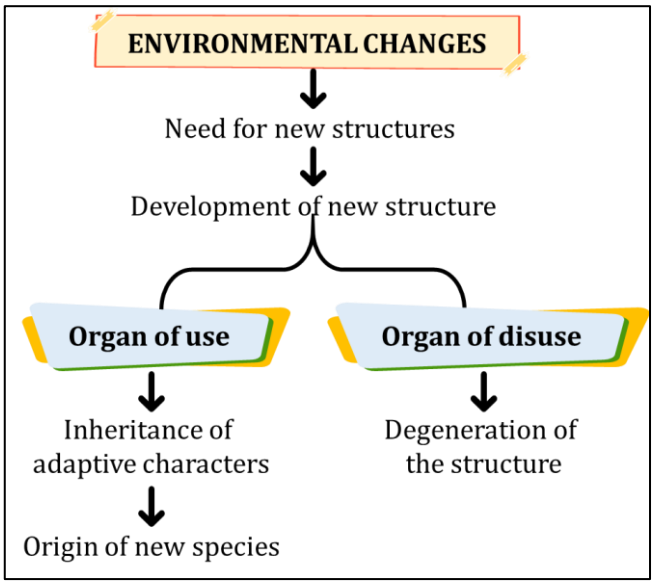
- First logical theory of evolution was proposed by a French naturalist Jean Baptiste de Lamarck (1744-1829)
- Book: ***Philosophie Zoologique*** (1809)

Basic Concepts of Lamarckism :

(i) **Internal vital forces**: Due to the presence of some internal vital forces all organisms have the tendency to increase in size of their organs or entire body.

(ii) **Effect of environment and new needs**: Environment influences all type of organisms. Changing environment gives rise to new needs. New needs or desires produce new structures (doctrine of desire/ appetency) and change habits of the organism.

(iii) **Use and disuse of organs**: If an organ is constantly used over generations, it would be better developed whereas disuse of organ results in its degeneration (vestigial organs).



(iv) **Inheritance of acquired characters**: During the life time of an organism, new characters develop due to internal vital forces, effect of environment, new needs or use and disuse of organs.
All these acquired characters are inherited from one generation to another. By continuous inheritance through several generations, the variations are accumulated up to such extent that they can give rise to new species.

Examples:

1. Long neck and forelimbs of **giraffe**:
Lamarck gave the example of Giraffes who in an attempt to forage leaves on tall trees had to adapt by elongation of their necks. As they passed on this acquired character of elongated neck to succeeding generations, Giraffes, slowly over the years came to acquire long necks.
2. **Aquatic birds** stretched their toes and developed web.
3. **Snakes** lost their legs.

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Snakes have evolved from lizard like ancestors which had two pairs of limbs. The continuous creeping through holes and cervices made snakes body elongated and due to continuous disuse of limbs because they hinder while creeping in burrows result in loss of their limbs.

Lamarck had said that evolution of life forms had occurred but driven by use and disuse of organs. Nobody believes this conjecture any more.

Diagram showing elongation of neck in giraffe according to Lamarckism

Criticism of Lamarckism:-

Disproved the Lamark's theory, inheritance of acquired characteristics.

(1) **Weismann's** Theory of **Continuity of Germplasm**:

- Weismann cut off the tails of rats for as many as 22 generations and allowed them to breed, but tailless or reduced tailed rats were never born.
- On the basis of this experiment Weismann proposed the theory of continuity of germplasm.
- According to this theory -
  Two types of protoplasms are present in an organism, **germplasm** and **somatoplasm**.
  There is a continuity of germplasm and the variations influencing the germ cells are only inherited but the somatoplasm is not transmitted to the next generation, hence it does not carry variations to next generation.

(2) **Boring of ear pinna and nose** in **Indian women** is never inherited to the next generations.

(3) **Chinese women** used to wear **iron shoes** in order to have small feet, but they still have normal feet.

Neo-Lamarckism :-

- According to Neo Lamarckism, **"Changing environment may create some physical and chemical changes in somatoplasm of organisms, which may affect their germplasm also and such acquired characters can inherit."**
- Many experiments were done to support this but they were not convincing and satisfactory.

Theories of Organic Evolution-Darwinism/Theory of Natural Selection :

- Charles Robert Darwin was born on 12th Feb. 1809 in England.
- Darwin travelled by **H.M.S. Beagle ship**, which left on 27 Dec. 1831 and returned on 02 Oct. 1836 through **S. America, S. Africa, Australia** & **Galapagos Islands**.
- Darwin was influenced by two books-
  (i) **"Principles of population"** of Malthus
  (ii) **"Principles of geology"** of Charles Lyell

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- **Alfred Wallace**, a naturalist who worked in **Malay Archipelago** had also come to similar conclusions around the same time and he sent his conclusions to Darwin in form of a chart.
- This theory was later on explained by Darwin in his book **'On the origin of species by means of Natural selection'** (1859).

Basic Concepts of Darwinism :

Branching Descent and Natural Selection are the two key concepts of Darwinian Theory of evolution.

Natural selection is based on certain observations which are factual.

(i) Over production:

- All organisms have the capability to produce enormous number of offspring or organisms (multiply in geometric ratio).
- Hence, theoretically population size will grow exponentially if everybody reproduced maximally (this fact can be seen in a growing bacterial population) but the fact is that population sizes in reality are limited.

(ii) Struggle for existence:

- Natural resources are limited and populations are stable in size (except for seasonal fluctuation) means that there had been competition for resources. Only some survived and grew at the cost of others that could not flourish. This is called struggle for existence.
- It is of three types -
  (a) Intra specific struggle: It is competition among the individuals of same species for same needs like food, shelter and breeding. (Most acute type of struggle)
  (b) Inter specific struggle: It is the struggle among the individuals of different species for food and shelter. It is the most potent force for organic evolution.
  (c) Environmental struggle: This struggle is between the organisms and their environment. All organisms struggle with cold, heat, wind, rain, drought, flood etc.

(iii) Variations and heredity:

- Members of a population vary in characteristics (in fact no two individuals are alike) even though they look superficially similar i.e. population has built in variation in characteristics.
- Those characteristics which enable some to survive better in natural conditions (climate, food, physical factors, etc.) are called adaptive or useful variations while others are called as non-adaptive or harmful variations.
- The novelty and brilliant insight of Darwin was, he asserted that variations, which are heritable and which make resource utilisation better for few (adapted to habitat better) will enable only those to reproduce and leave more progeny.

(iv) Natural selection/ Survival of the fittest:

- Individuals with more adaptive variations are **"better fit"** than the individuals with less adaptive variations. Hence, those who are better fit in an environment would be selected by nature and leave more progeny than others. Darwin called it natural selection and implied it as a mechanism of evolution.

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- Fitness is the end result of the ability to adapt and get selected by nature.
- The fitness, according to Darwin, refers ultimately and only to reproductive fitness.
- It is observed that all adult individuals of a population don't have equal chances of mating; some males with better phenotype are preferred by females. This is called **Sexual selection**.

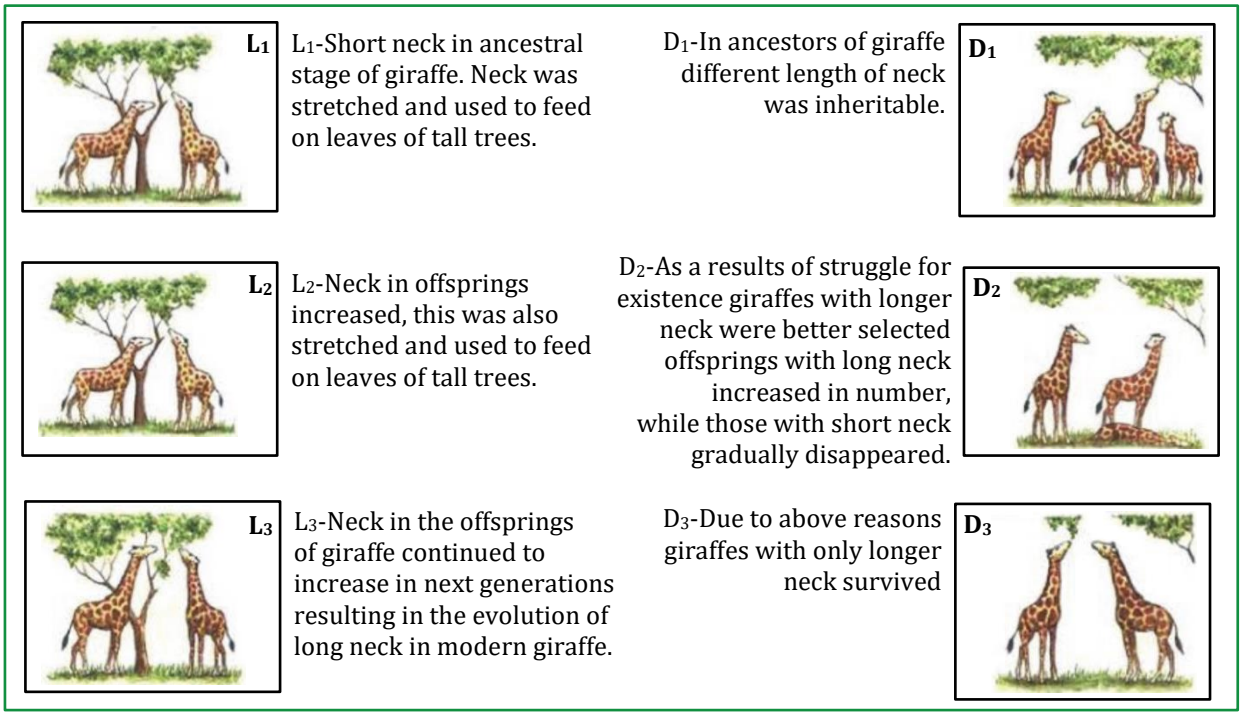
(v) Origin of New species:

- As a result of heritable variations and natural selection there would be a change in population characteristic and hence new forms appears to arise.

Criticism of Darwinism :

1. The main drawback of this theory is that Darwin didn't have the knowledge of genetics and he had no satisfactory explanation for the cause, origin and inheritance of variations.
2. This theory only explained the survival of fittest but was unable to explain the arrival of fittest
3. Darwin was unable to explain why in a population only a few individuals develop useful variations and others have harmful variations.
4. Criticism of Darwinism was based on sexual selection. Why only females have the right of selection for mating?
5. Darwin couldn't explain the existence of vestigial organs.
6. Darwin was unable to differentiate the somatic and germinal variations.

Comparison of Lamarckism and Darwinism :


L1
L1-Short neck in ancestral stage of giraffe. Neck was stretched and used to feed on leaves of tall trees.
D1-In ancestors of giraffe different length of neck was inheritable.
D1
L2
L2-Neck in offsprings increased, this was also stretched and used to feed on leaves of tall trees.
D2-As a results of struggle for existence giraffes with longer neck were better selected offsprings with long neck increased in number, while those with short neck gradually disappeared.
D2
L3
L3-Neck in the offsprings of giraffe continued to increase in next generations resulting in the evolution of long neck in modern giraffe.
D3-Due to above reasons giraffes with only longer neck survived
D3

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Theories of Organic Evolution- Mutation Theory & Neo-Darwinism :

Mutation Theory :

- This theory was proposed by **Hugo de Vries** based on his work on **evening primrose (*Oenothera lamarckiana*)**.
- Large differences arising suddenly in a population are called mutations. Actually, mutations are sudden changes of genetic material (DNA) and hence all are inheritable.
- In addition to recombination, mutation is another phenomenon that leads to variation in DNA.
- Mutation is a discontinuous source of variations and provides raw material for evolution.
- According to Hugo de Vries it is mutation which causes evolution and not the minor variations (heritable) that Darwin talked about.
- Mutations are random and directionless while Darwinian variations are small and directional.
- Evolution for Darwin was gradual while de Vries believed mutation caused speciation and hence called it saltation (single step large mutation).

Criticism-

(i) Natural mutations are not very common as Hugo de Vries thought.

(ii) Mutations are normally recessive & harmful, while the characters taking part in evolution are usually dominant.

BEGINNER'S BOX-4 LAMARCKISM, DARWINISM

1. What was the basic principle of Lamarckism :
(1) Inheritance of acquired characters (2) Survival of the fittest
(3) Natural selection (4) Variations

2. Which scientist gave the 'Theory of Continuity of Germplasm' :
(1) Weismann (2) Mendel (3) Lamarck (4) Darwin

3. Darwin explained origin of species through :
(1) Hybridization (2) Mutation
(3) Acquired characters (4) Natural selection

4. The ship on which Darwin worked as naturalist was :
(1) Beagle (2) Century (3) Seagel (4) Norway

5. Darwin was influenced by the writings of :
(1) Malthus (2) Wallace (3) Lyell (4) All of them

6. Who attempted to solve the mechanism of organic evolution for the first time :
(1) Haeckel (2) De Vries (3) Lamarck (4) Darwin

7. The weakest point of Darwinism was that it had no explanation for :
(1) Struggle for existence (2) Survival of the fittest
(3) Variations (4) Enormous rate of production

8. Book '*Philosophie Zoologique*' published in the year 1809 was written by :
(1) Darwin (2) Lamarck (3) De Vries (4) Mendel

9. Mutation theory to explain mechanism of evolution was given by Hugo de Vries and he experimented on the:
(1) Garden pea (2) Fruit fly (3) China rose (4) Evening primrose

TG: @Chalnaayaaar

10. Who published the book "Origin of Species by Natural Selection" in 1859
(1) Lamarck (2) Darwin (3) Wallace (4) Oparin

11. Who gave first logical theory to solve the mechanism of organic evolution?
(1) Haeckel (2) De Vries (3) Lamarck (4) Darwin

12. Darwin's theory states that :-
(1) Characters are acquired through inheritance
(2) Species change morphologically with time
(3) Nature selects organisms which are better fit
(4) Evolution is due to effect of environment

Neo-Darwinism/Modern Synthetic Theory of Organic Evolution :

- Neo-Darwinism is a modified form of Darwinism along with recent researches of **Weismann, De Vries, Stebbins, Dobzhansky, Sewall Wright, Mayr** etc.
- According to this theory following factors are responsible for formation of new species-

(i) **Rapid multiplication**

(ii) **Limited food and space**

(iii) **Struggle for existence**

(iv) **Genetic variations**

(a) Gene recombination - New combinations of genes which are usually caused by the crossing over during gametogenesis. It is continuous and common source of variation in a sexually reproducing population.

(b) Mutation - Discontinuous source of variations

(c) Hybridization - It is crossing of organisms which are genetically different in one or more traits.

(d) Gene migration & Gene flow - When migration of a section of population to another place and population occurs, gene frequencies change in the original as well as in the new population. New genes/alleles are added to the new population and these are lost from the old population. There would be a gene flow if this gene migration, happens multiple times.

(e) Genetic drift - If the change in gene frequency occurs by chance, it is called genetic drift.

(v) **Natural Selection:** Natural selection is a process in which heritable variations enabling better survival are enabled to reproduce and leave greater number of progenies.
A critical analysis makes us believe that variation results in changed frequency of genes and alleles in future generation. Coupled to enhance reproductive success, natural selection makes it look like different population and lead to new species formation.

(vi) **Isolation:** Isolation is a segregation of populations by some barriers which prevent interbreeding. The reproductive isolation between the populations due to certain barriers (E.g. Geographical isolation) leads to the formation of new species.

Genetic Drift (Sewall Wright effect) -

- Random change of gene/allelic frequencies in a population merely by chance is called genetic drift.
- It operates rapidly in small population.
- It is due to habitat fragmentation, isolation, natural calamities or any epidemics.
- **Founder effect** and **bottleneck effect** are two forms of genetic drift.

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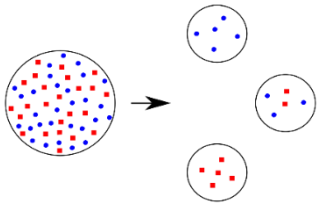
(a) Founder effect-

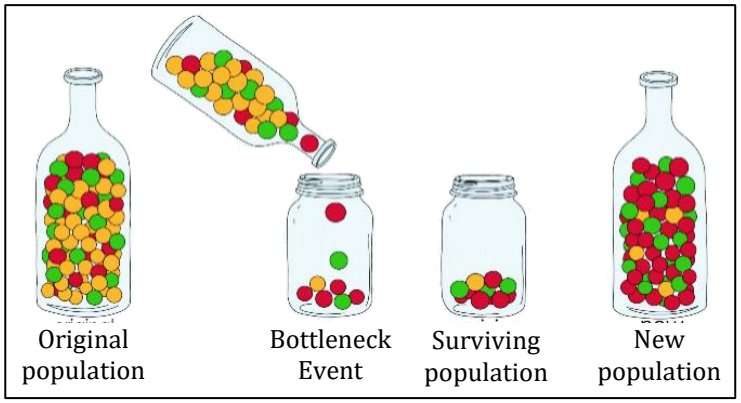
When a section of population gets isolated or migrated or drifted from original population, then this section becomes genetically different from the original population due to change in allelic frequency because gene pool of this section may contain some alleles in a very low frequency or may lack a few alleles.



Sometimes the change in allelic frequency is so different in the new sample of population that they become a different species. The original drifted population becomes founders and the effect is called founder effect.

(b) Bottleneck effect-

Bottlenecks are the natural calamities like earthquakes, volcanic eruptions, floods, storms etc. A sudden change in the environment may drastically reduce the size of a population and now this population may be genetically different from the original population. Certain alleles may have more frequency among the survivors, others may be less, and some may be absent altogether.



If a population that has passed through a bottleneck ultimately recovers in size, it may have low levels of genetic variation for a long period of time and this may produce a new species.

Hardy- Weinberg Principle :

- In a given population one can find out the frequency of occurrence of alleles of a gene or a locus. This frequency is supposed to remain fixed and even remain the same through generations.
- This principle says that allele frequencies in a **large, randomly mating & non-evolving population** are stable and remain constant from generation to generation. The gene pool (total genes and their alleles in a population) remains a constant. This is called **genetic equilibrium**. Sum total of all the allelic frequencies is **1**.

  $p + q = 1$

  Where: **p** - Frequency of dominant allele (A)

  q - Frequency of recessive allele (a)

- The binomial expansion of this equation is:

  $p^2 + 2pq + q^2 = 1$

  Where: **p^2** – Frequency of individuals with genotype **AA**

  q^2 – Frequency of individuals with genotype **aa**

  2pq – Frequency of individuals with genotype **Aa**

- When frequency measured, differs from expected values, then the difference (direction) indicates the extent of evolutionary change.

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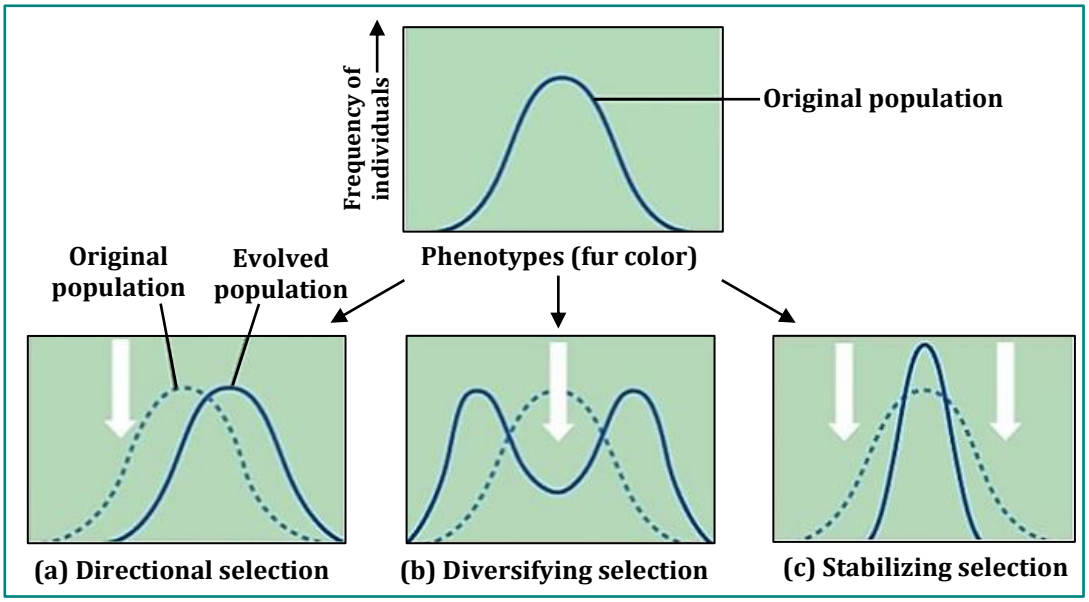
- Disturbance in genetic equilibrium, or Hardy- Weinberg equilibrium, i.e., ***change of frequency of alleles in a population would then be interpreted as resulting in evolution***.
- Five factors are known to affect Hardy-Weinberg equilibrium. These are-

  1. Gene migration or gene flow 2. Genetic drift 3. Mutation
  4. Genetic recombination 5. Natural selection

8. Types of Natural Selection :



(1) Stabilizing selection:

- It favours the average or normal phenotype and eliminates the extreme variants.
- After this natural selection mean value never change.
- Peak gets higher and narrower because more individuals acquire mean character value.
- Always operates in constant environment.

  e. g. Mortality in human babies: The optimum birth weight favoured by stabilizing selection is 7.3 pounds. New born infants less than 5.5 pounds and more than 10 pounds have the highest mortality rate.

(2) Directional/ Progressive selection:

- It favours one extreme value and eliminates another extreme value and average value.
- After this natural selection mean value always changes.
- Peak shifts in one direction because more individuals acquire value other than the mean character value.
- Always operates in changing environment.

  e. g. (i) Industrial melanism
  (ii) DDT resistance in pests

(3) Disruptive selection:

- In this natural selection members of both extreme are selected simultaneously and average value get rejected.

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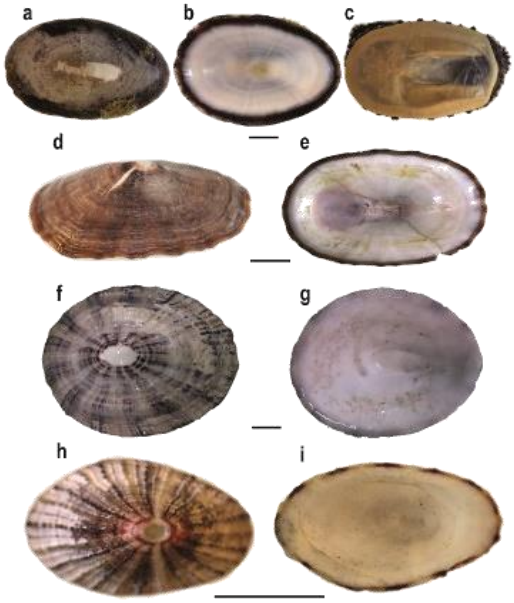
- After this natural selection two peaks are formed because more individuals acquire peripheral character value at both ends of the distribution curve.
  e. g. ***Shell pattern in limpets***: Shell patterns of limpets (marine molluscs) present a continuous, ranging from pure white to dark tan. The white or light-coloured limpets camouflaged with white barnacles and tanned ones are protected on the tanned coloured rocks. Limpets of intermediate shell patterns, being conspicuous are preyed by predatory shore birds, resulting in disruptive selection.



Reproductive Isolation :

- It is the prevention of inter breeding between the populations of two different or closely related species.
- It maintains the characters of the species but can lead to the origin of new species.
- This mechanism of reproductive isolation was explained by Stebbins in his book **'Process of Organic Evolution'**.

Two main subtypes of reproductive isolation are-

1. **Prezygotic isolation** - Prevention of mating and the formation of hybrid zygote.
   - **(i) Ecological isolation**: Isolation due to different habitats of two species. For example, one may be living in fresh water and other in the sea.
   - **(ii) Temporal isolation**: Due to difference in breeding seasons or flowering times of two species.
   - **(iii) Behavioural isolation**: Due to difference in sexual or coitus behaviour of two species.
   - **(iv) Mechanical isolation**: Due to incompatible external genital organs.
   - **(v) Gametic isolation**: The sperms and ova of different species can't fuse due to difference in their surface chemicals.

2. **Postzygotic isolation** - A hybrid zygote is formed but it may not develop into a viable fertile adult.
   - **(i) Hybrid inviability**: Hybrid zygote fails to develop. In plants, embryos arising from interspecific cross are not viable.
   - **(ii) Hybrid sterility**: Hybrid adults are sterile and do not produce gametes.
     e. g. Mules and hinny
   - **(iii) Hybrid breakdown**: Sometimes inter specific mating produces a hybrid, which give rise to next hybrid by back cross but they have reduced vigour or fertility or both.

- **Exception**: **Tigon** (African lioness x Asian tiger) and **Liger** (Male lion x Female tiger) hybrids are **fertile** but these species do not interbreed naturally.

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Examples of Natural Selection and Artificial Selection :

(1) Industrial Melanism - This phenomenon was studied by **Bernard Kettlewell** in England.

(a) (b)

Figure showing white - winged moth and dark - winged moth (melanised) on a tree trunk

(a) In unpolluted area (b) In polluted area

- In a collection of moths (***Biston betularia***) made in 1850s, i.e., before industrialization set in, it was observed that there were more white-winged moths on trees than dark-winged or melanised moths.
- However, in the collection carried out from the same area, but after industrialization, i.e., in 1920, there were more dark-winged moths in the same area, i.e., the proportion was reversed.
- The explanation put forth for this observation was that 'predators will spot a moth against a contrasting background'.
- Before industrialization set in, thick growth of almost white-coloured lichen covered the trees - in that background the white winged moth survived but the dark-coloured moths were picked out by predators.
- **Lichens** can be used as industrial pollution indicators. They will not grow in areas that are polluted.
- During post industrialization period, the tree trunks became dark due to industrial smoke and soot. Under this condition the white-winged moth did not survive due to predators while dark-winged or melanised moth survived.
- Hence, moths that were able to camouflage themselves, i.e., hide in the background, survived.
- This understanding is supported by the fact that in areas where industrialization did not occur e.g., in rural areas, the count of melanic moths was low.
- This showed that in a mixed population, those that can better-adapt, survive and increase in population size. Remember that no variant is completely wiped out.

(2) Drug resistance:

- The drugs which eliminate pathogens become ineffective in the course of time because those individuals of pathogenic species which can tolerate them survive and flourish to produce tolerant/resistant population.
- Excess use of herbicides, pesticides, etc., has only resulted in selection of resistant varieties in a much lesser time scale. This is also true for microbes against which we employ antibiotics or drugs against eukaryotic organisms/cell. Hence, resistant organisms/cells are appearing in a very less time scale of months or years and not centuries. **These are examples of evolution by anthropogenic action.**
- This also tells us that evolution is not a directed process in the sense of determinism. It is a **stochastic process** (random/by chance process) based on chance events in nature and chance mutation in the organisms.

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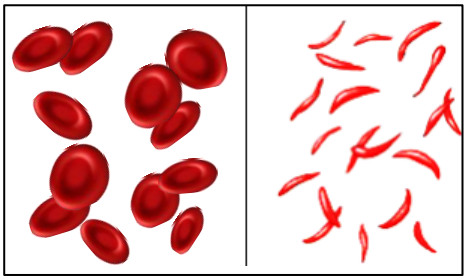
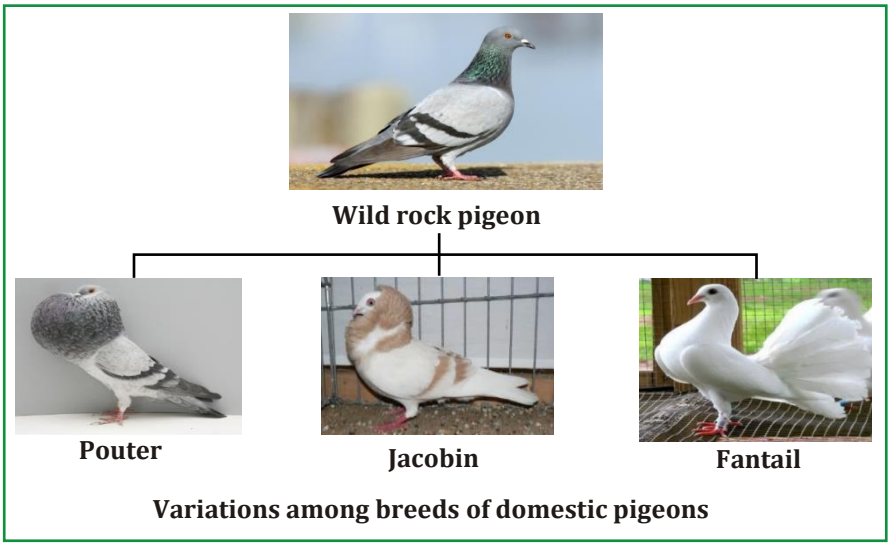
(3) Sickle cell anaemia and Malaria:

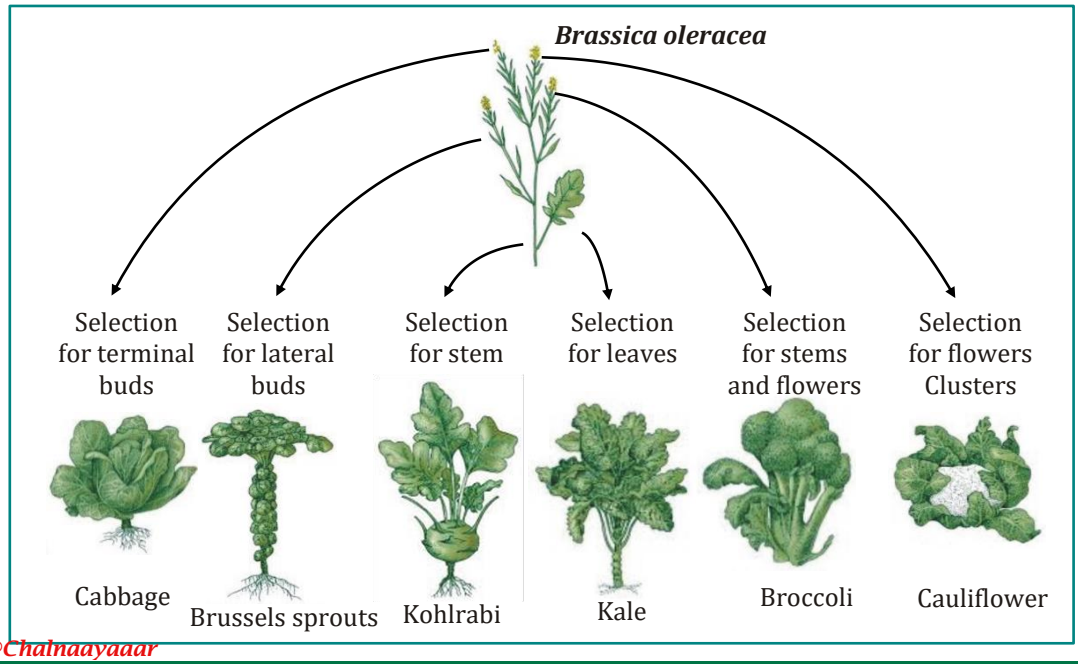


- Individuals, homozygous for sickle cell anaemia die at an early stage due to anaemia and the individuals in which heterozygous condition is present for this character, the RBC become sickle shaped on entry of plasmodium.
- In this type of RBC, malarial parasite can't have a normal growth and individuals become resistant towards malaria.
- The individuals with heterozygous condition have better chances of survival, hence are selected by nature.
- Thus, the process of natural selection maintains the abnormal form of haemoglobin along with the normal form in a region where malaria is common. This type of selection is called **Balancing selection**. It means the preservation of genetic variability is maintained by the selection of heterozygote which is called balanced polymorphism. But this kind of balancing selection is found very rarely in nature.

Artificial Selection -



Variations among breeds of domestic pigeons



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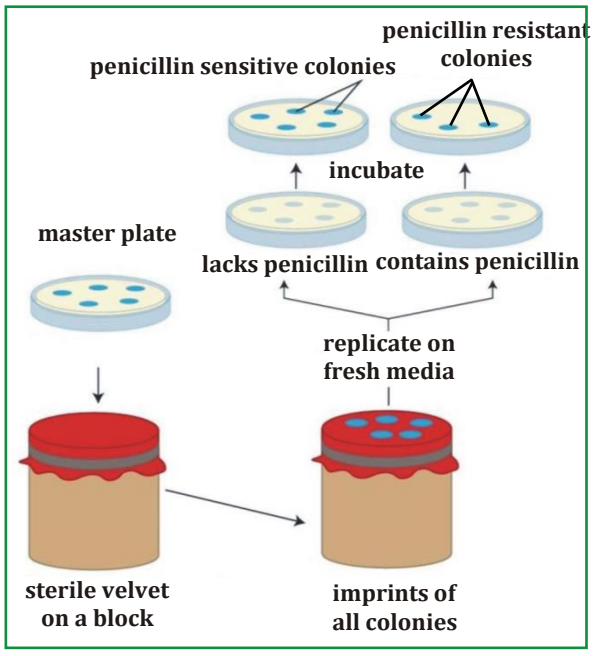
- Artificial selection is similar to natural selection except that the role of nature is taken over by man and the characters selected are of human use.
- Man has been taking the advantages of genetic variations for improving the qualities of domesticated plants and animals.
- By artificial selection animal breeders are able to produce improved varieties of domesticated animals like dogs, horses, pigeons, poultry, cows, goats, sheep and pigs from their wild ancestors.
- Similarly, the plant breeders have obtained improved varieties of useful plants like wheat, rice, sugarcane, cotton, pulses, vegetable, fruits etc.
- It is argued that if within hundreds of years, man could create new breeds, could not nature have done the same over millions of years?

Genetic Basis of Adaptations/Natural Selection and Lederberg's Experiment :

- The essence of Darwinian Theory about evolution is natural selection.
- The rate of appearance of new forms is linked to the life cycle or the life span.
- Microbes that divide fast have the ability to multiply and become millions of individuals within hours.
- A colony of bacteria (say A) growing on a given medium has built in variation in terms of ability to utilise a feed component. A change in the medium composition would bring out only that part of the population (say B) that can survive under the new conditions.
- In due course of time this variant population outgrows the others and appears as new species. This would happen within days.
- For the same thing to happen in a fish or fowl would take millions of years as life spans of these animals are in years. Here we say that fitness of B is better than that of A under the new conditions.
- Fitness or adaptive ability is based on characteristics which are inherited. It has a genetic basis. Hence, there must be a genetic basis for getting selected and to evolve.
- Microbial experiments show that pre-existing advantageous mutations when selected will result in observation of new phenotypes. Over few generations, this would result in Speciation.

Lederberg's Replica Plate Experiment :

- Performed by **Joshua Lederberg** & **Esther Lederberg**.
- They cultured the bacterial cells on agar plate and obtained many bacterial colonies. This multi colony agar plate is known as master plate.
- They prepared a replica of this master plate by gently pressing it on a velvet covered wooden block.
- Now they tried to prepare a replica on the agar plate which contains antibiotic penicillin. It was seen that some bacteria failed to grow on penicillin agar plate while some bacteria were able to grow and developed new colony.
- It was concluded that the bacteria which survived were penicillin resistant because they had penicillin resistant mutant gene which enabled them to survive in changed environment.



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- It means mutations are pre-adaptive and natural selection fixes them in a population over the generations.

Types of Speciation and Evolution :

SPECIATION-

- Formation of one or more new species from an existing species is called speciation. Speciations are of two types-
  (i) Divergent speciation
  (ii) Transformation speciation

  (i) Divergent speciation: When one or more new species are formed from an ancestor species.
  (a) Allopatric speciation: When a species split into two or more geographically isolated populations and these populations finally form a new species. It is called allopatric speciation **e.g.** Darwin finches.
  (b) Sympatric speciation: In this type of speciation a sub population becomes reproductively isolated from its parental population. It is the formation of species without geographical isolation.
  e.g. mainly present in plants due to polyploidy.

  (ii) Transformation speciation: When an ancestor species changes into a new species.
  (a) Phyletic speciation: Ancestor species changes into new species by gradual changes in thousands of years.
  e.g. Eohippus → Mesohippus → Merychippus → Pliohippus → Equus
  (b) Quantum speciation: In this process suddenly, major changes appear in ancestor species and ancestor species immediately changed into new species. No connective links are present in this type of speciation. It is caused by major mutation.

★ Golden Key Points ★

- Unit of natural selection is an **individual.**
- Unit of evolution is **Population.**
- Habitat fragmentation and genetic drift may accentuate (emphasis) the variations leading to appearance of new species and hence evolution.
- Homology is accounted for the idea of branching descent.
- According to de Vries evolution is a **jerky and discontinuous** process.
- The original idea of survival of fittest was proposed by **Herbert Spencer**.

BEGINNER'S BOX-5

NEODARWINISM, NATURAL SELECTION, REPRODUCTION ISOLATION, SPECIATION, MIMICRY

1. New breeds in domestic dogs are developed by :
(1) Sexual selection (2) Natural selection
(3) Youth selection (4) Artificial selection

2. Which scientist gave the initial idea of survival of the fittest ?
(1) Wallace (2) Spencer (3) Darwin (4) Mendel

3. Species separated by geographical barriers are called :-
(1) Allopatric (2) Sympatric (3) Sibling (4) Endemic

4. Genetic drift in mendelian population takes place in :-
(1) Small population (2) Large population
(3) Oceanic population (4) Never occurs

5. Industrial melanism is an example of :-
(1) Natural selection (2) Mutation (3) Racial difference (4) Predation

6. If a starfish possess 6 arms instead of 5, it is an example of :
(1) Variation (2) Metamorphosis (3) Biogenesis (4) Evolution

7. Neo-Darwinism believes that new species develop through :
(1) mutations (2) hybridization
(3) mutations with natural selection (4) none of the above

8. Which one is linked to evolution ?
(1) extinction (2) competition (3) variation (4) reproduction

9. Breeding is possible between two member of :-
(1) Genus (2) Family (3) Order (4) Species

10. De Vries gave his mutation theory on organic evolution while working on
(1) *Oenothera lamarckiana* (2) *Drosophila melanogaster*
(3) *Pisum sativum* (4) *Althea rosea*

11. The ultimate source of variation is :
(1) Mutation (2) Sexual reproduction
(3) Natural selection (4) Hormonal action

12. One of the important consequences of geographical isolation is :-
(1) No change in the isolated fauna
(2) Preventing Speciation
(3) Speciation through reproductive isolation
(4) Random creation of new species

13. Mortality in human babies due to birth weight is an example of?
(1) Stabilizing selection (2) Directional selection
(3) Disruptive selection (4) Both (1) & (3)

14. The rate of appearance of new forms is linked to :-
(1) Life cycle (2) Natural selection
(3) Death rate (4) None of the above

15. Which of the following have genetic basis :-
(1) Adaptive ability (2) Fitness (3) Both (1) and (2) (4) None of these

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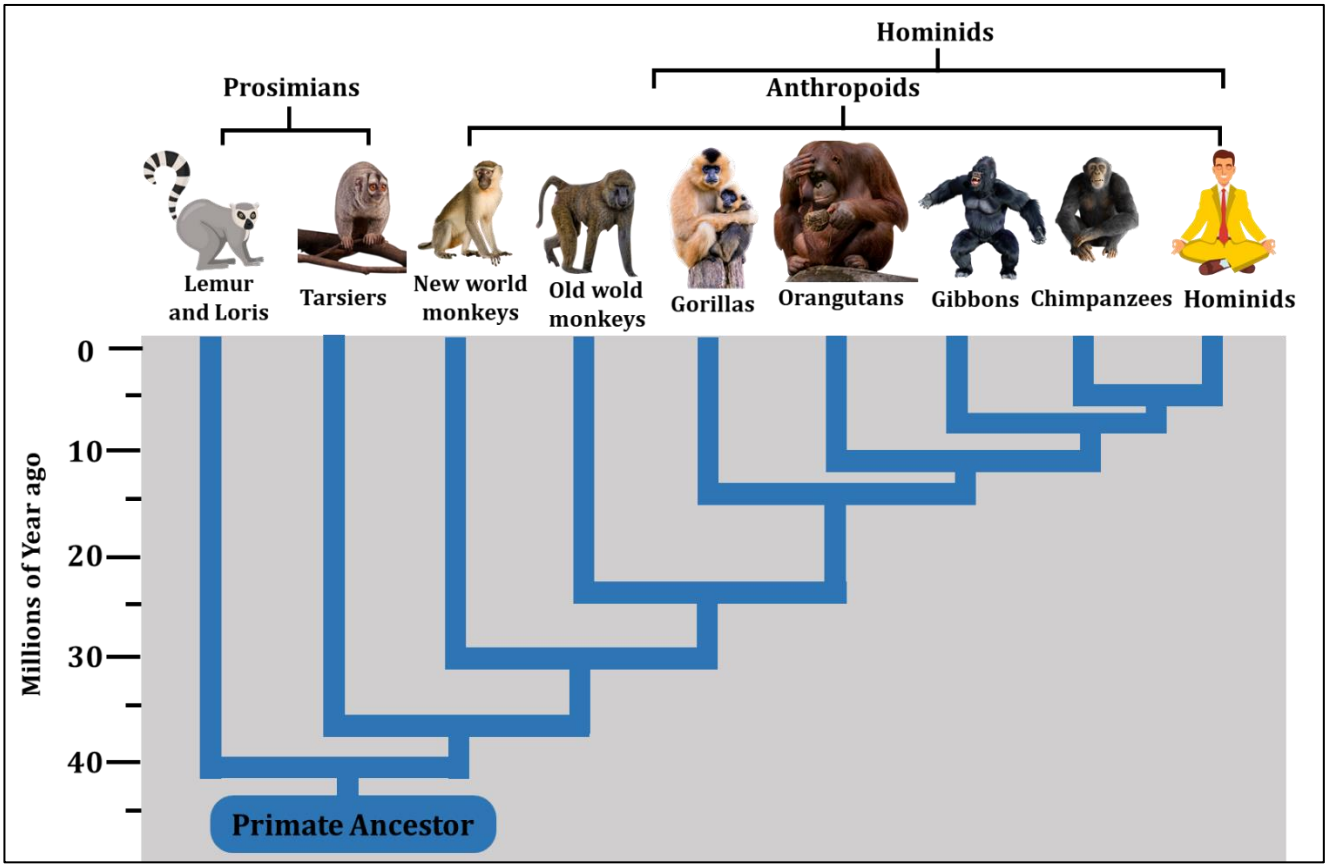
9. Origin and Evolution of Man :

- Human is a member of order ***Primata*** of class **Mammalia**.
- First real primate ancestors were ***tree shrews***.



Monkeys - 2 types of monkeys:

New world monkeys (South & North America)

- Long & prehensile tail
- Dental formula $\frac{2133}{2133} = 36$
- Menstruation cycle in female - absent

e.g.: Spider monkey

Old world monkeys (Africa, Asia)

- Long or short, non-prehensile tail
- Dental formula $\frac{2123}{2123} = 32$
- Menstruation cycle in female - present

e.g.: Rhesus (Macaca), Baboon

Hence, old world monkeys are closer to human

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Evidences for common origin of human & apes:

(1) **Banding pattern** of chromosome no. **3** & **6** of human and chimpanzee is 100% similar.

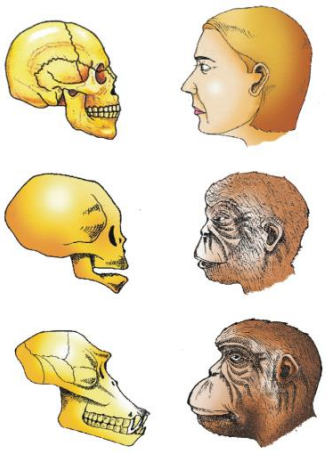
(2) The skull of **baby chimpanzee** is more like **adult human** skull than adult chimpanzee skull.

(3) Composition of **Hb** is same in both human and chimpanzee. Only one amino acid is different in human and gorilla.

(4) Blood group of **AB** series is present in both and **plasma protein** is also same.

(5) **Menstrual cycle** is present in females of both.

(6) **Tail** is absent in both and have **grasping hands with opposable thumbs**.



A comparison of the skulls of adult modern human being, baby chimpanzee and adult chimpanzee

Differences between Human and apes

Apes		Human	
1.	Semi erect posture	1.	Complete erect posture with bipedal locomotion
2.	Thick growth of hair on whole body	2.	Thick growth of hair only on certain part of body
3.	Less cranial capacity (450cc) & less intelligent	3.	More cranial capacity (1300-1600cc) & more intelligent
4.	Forelimbs longer than hind limbs	4.	Forelimbs shorter than hind limbs
5.	'U' shaped jaw & chin absent	5.	Semi-circular jaw & chin present
6.	Thumb movements are less developed	6.	Thumb movements are more developed

Human Evolution:

(A) **Ape Fossils** - About 15 mya, primates called Dryopithecus and Ramapithecus were existing. They were hairy and walked like gorillas and chimpanzees.

(1) Proconsul/ Dryopithecus:

- It is considered as **common ancestor** of man and direct ancestors of modern-day apes.
- They had semi erect posture, thick hair, U shaped jaws, larger and sharper teeth and were vegetarian.
- Their forelimbs were longer than hind limbs and they were forest dwellers.

(2) Ramapithecus
(3) Shivapithecus] Fossils discovered from **Shivalik hills in India**

(4) Kenyapithecus - Fossils discovered from **Kenya**.

Ramapithecus was *more* **man-like** while ***Dryopithecus*** was *more* **ape-like**.

(B) **Ape man fossils** - *Australopithecus*

- **2 mya**, Australopithecines probably lived in East African grasslands.
- Evidence shows they hunted with stone weapons but essentially ate fruit.
- It is also considered as ***connecting link*** between ***apes*** and ***man***.

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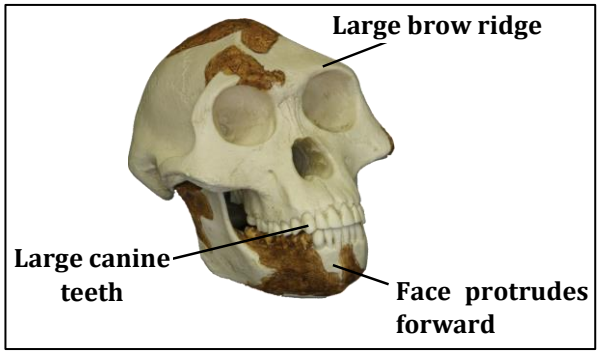
- Few fossils of man-like bones have been discovered in **Ethiopia and Tanzania.** These revealed hominid features leading to the belief that **about 3-4 mya, man-like primates walked in eastern Africa.** They were probably **not taller than 4 feet** but **walked up right.**

(i) Ape-like characters:
- Less cranial capacity **(600 c.c.)**
- Thick growth of hair
- U shaped jaw **(prognathous face)**
- Larger and sharper teeth

(ii) Man-like characters:
- Complete erect posture and **Bipedal locomotion** (first man who stood erect)
- Forelimbs shorter than hind limbs
- **Vertebral column** with distinct lumber curve



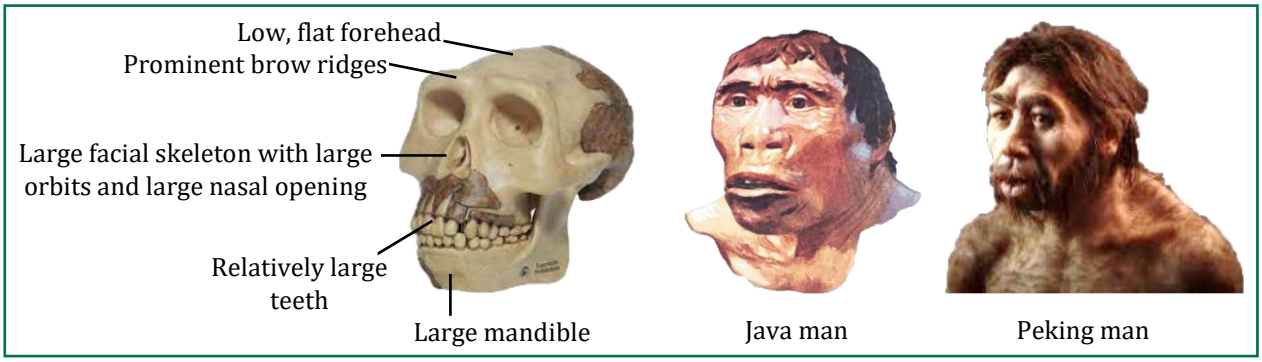
Prehistoric Man :

These extinct species of *Homo* are called as prehistoric species of man.

(1) *Homo habilis*:
- First human-like being.
- **First tool maker man** or **Handy man**, they lived in caves.
- They probably did not eat meat.
- The brain capacities were between **650-800 cc**.
- Its fossils were discovered from **2 million years old** rocks in **Africa**.

(2) *Homo erectus*:
- They existed about **1.5 million years** ago.
- They had **large brain** with a cranial capacity around **900 cc.**
- They were cave dwellers and probably **ate meat**.
- Many subspecies are discovered of ***Homo erectus*** as given below

(a) Java man (*Homo erectus erectus/ Pithecanthropus erectus*):
- Its fossils discovered in **Java** in 1891.
- **First man who used fire** for hunting, protection and cooking.
- They used tools of bones and stones.
- Their cranial capacity was 800-1000 cc **(avg. 900 cc)**
- They were omnivorous and cannibalism have also found.



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(b) Peking man (*Homo erectus pekinensis/ Sinanthropus erectus*):

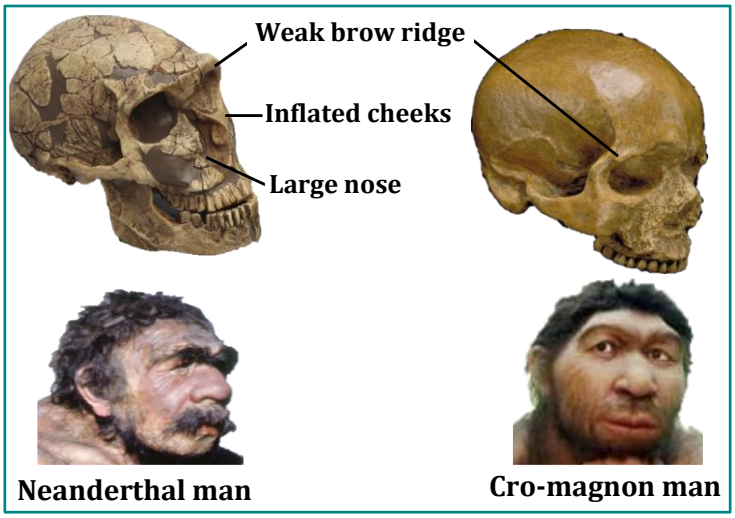
- **W.C. Pei** discovered the fossils from China.
- They used fire for cooking meat and protection.
- Their cranial capacity was 850-1300 cc **(avg. 1050 cc)**
- They were omnivorous and cannibalism have also found.

(3) *Homo sapiens*:

- Many subspecies are discovered of *Homo sapiens* as given below

(a) Neanderthal man (*Homo sapiens neanderthalensis*):

- They lived near **east** and **central Asia** between **1,00,000 - 40,000 years** back, fossil was discovered in **Neanderthal valley of Germany**.
- They had a brain size of **1400 cc** (similar as modern man).
- They **buried their dead** and probably believed in **immortality of soul**.
- They used hides (skin of animals) to protect their body.
- They lived in huts and were **omnivorous** by nature.
- Development of **speech centre** and language started.



(b) Cro-Magnon man (*Homo sapiens fossilis*):

- Origin and evolution **50,000 to 10,000 years** ago.
- Fossils discovered from **Cro-Magnon rocks of France.**
- Cranial capacity: **1650 c.c.(maximum)**
- They lived in caves and omnivorous by nature.
- They had semi-circular jaw and **orthognathous face** with larger forehead and well-developed chin.
- Speech and language centre were well developed in them.
- They wore clothes of animal skin.
- This man was hunter and used domesticated dogs in hunting, hence **domestication** was started by this man.
- They also **painted beautiful paintings** on **cave walls**. Pre-historic cave art developed about **18,000 years ago,** which can be seen at Bhimbetka rock shelter in **Raisen district** of Madhya Pradesh.

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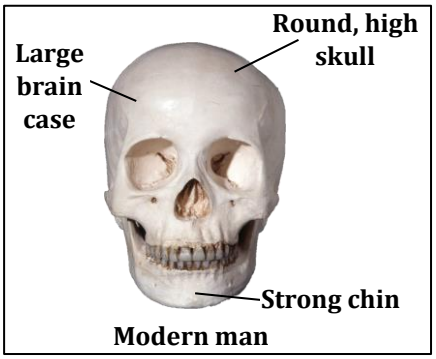
(c) Modern man (*Homo sapiens sapiens*):



- During ***ice age*** between **75,000-10,000 years** ago modern Homo sapiens arose.
- It arose in **Africa** and moved across continents and developed into distinct races (**Caucasoid, Negroid, Mongoloid** and **Australoid**).
- This is the **man of today** having a brain capacity of 1300 - 1600 cc **(avg. 1450 cc)**.
- This man has well developed chin, well developed speech centre, smaller forehead and reduced body hair.
- Semi-circular jaw and **orthognathous face**.
- It is **omnivorous** by nature.
- **Agriculture** was also started by this man. Agriculture came around **10,000 years back** and human settlements started.

Golden Key Points

- Chimpanzee is closest ape to human.
- Gibbon is the only ape that found in India (forests of Assam).
- **Homo erectus** is the **direct ancestor of Homo sapiens.**
- **Cromagnon man** is the **direct ancestor of modern man (*Homo sapiens sapiens*).**

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BEGINNER'S BOX-6 HUMAN EVOLUTION

1. Fossils of *Pithecanthropus* have been recovered from :
(1) China (2) Germany (3) Java (4) Japan

2. Ancestor of man who first time showed bipedal movement
(1) Cro-magnon (2) *Australopithecus*
(3) Java apeman (4) Peking man

3. *Homo erectus* is biological name of :
(1) Modern man (2) Neanderthal man
(3) Java man (4) Peking and Java man

4. The probable direct ancestor of modern man is :
(1) Java man (2) Peking man
(3) Cromagnon man (4) Neanderthal man

5. The probable first prehistoric man was :
(1) *Ramapithecus* (2) *Homo habilis*
(3) *Australopithecus* (4) *Sinanthropus*

6. On which continent maximum fossils of prehistoric man have been found ?
(1) Africa (2) Europe (3) Asia (4) America

7. The proper burial of dead for the first time started with which prehistoric man :
(1) Peking man (2) Neanderthal man
(3) Java man (4) Cromagnon man

8. Cranial capacity of Cro-magnon man was :
(1) 900 cc (2) 1075 cc (3) 1450 cc (4) 1600 cc

9. Fire for protection and cooking was first used by :
(1) Neanderthal man (2) Cro-magnon man
(3) Java man (4) Peking man

10. Coloured rock paintings were first done by :
(1) Cro-magnon man (2) Java ape man
(3) Peking man (4) Neanderthal man

11. Which of the following statement is correct :-
(1) Proconsul was ancestor of man and ape
(2) Proconsul was ancestor of man and not of ape
(3) Apes were ancestor of man anatomically
(4) None of them

12. Which of the following is closest to man :-
(1) Chimpanzee (2) Gorilla
(3) Old world Monkey (4) Australopithecus

TG: @Chalnaayaaar

BEGINNER'S BOX — ANSWERS KEY

BEGINNER'S BOX-1	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	2	1	3	3	1	3	3	3	3	2
	Que.	11	12	13	14	15					
	Ans.	3	1	3	1	3					

BEGINNER'S BOX-2	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	3	4	3	2	2	1	2	2	2	2
	Que.	11	12	13	14	15					
	Ans.	1	3	4	2	1					

BEGINNER'S BOX-3	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	1	4	4	1	4	4	4	2	1	1
	Que.	11	12	13	14	15					
	Ans.	4	3	2	2	4					

BEGINNER'S BOX-4	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	1	1	4	1	4	3	3	2	4	2
	Que.	11	12								
	Ans.	3	3								

BEGINNER'S BOX-5	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	4	2	1	1	1	1	3	3	4	1
	Que.	11	12	13	14	15					
	Ans.	1	3	1	1	3					

BEGINNER'S BOX-6	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	3	2	4	3	2	1	2	4	3	1
	Que.	11	12								
	Ans.	1	4								

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- Changes in planets and stars from their origin to death - Stellar evolution
- Changes in inorganic matter and elements with time - Inorganic evolution
- Evolution is a slow but continuous process which never stops- **Buffon**
- **Dollo's law** - It states that evolution is irreversible.
- Father of paleontology - **Leonardo da Vinci**
- Founder of modern paleontology - **George Cuvier**
- Study of plant fossils - **Paleobotany**
- Study of animal fossils - **Paleozoology**
- Three types of rocks are found on earth - Sedimentary, Igneous and metamorphic.
- Fossil parks of India -
  (i) Birbal Sahni institute of paleobotany, Lucknow
  (ii) 50 million year old fossil forests preserved in Mandla district (MP)
  (iii) 100 million year old fossil forest in Rajmahal Hills, Bihar
  (iv) 260 million year old coal forming forest in Orrisa
- Giraffe, Zebra and hippopotamus are found only in Africa.
- Mainland of human evolution is Africa.
- Book **'Genetics and the origin of species'** was written by Dobzhansky.
- **Asiatic apes –** Hylobates (Gibbon 100cc) - India
  Orangutan (400cc) - Indonesia
  African apes – Gorilla (500cc)
  Chimpanzee (400cc)
- The course of cultural evolution is divided into 3 ages:
  (i) Palaeolithic - Age of tools of stones and bones.
  (ii) Mesolithic - Age of animal husbandry, language, reading & writing.
  (iii) Neolithic -
  (a) Bronze age - Age of agriculture, knowledge and use of clothes
  (b) Iron age - The present age.